



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

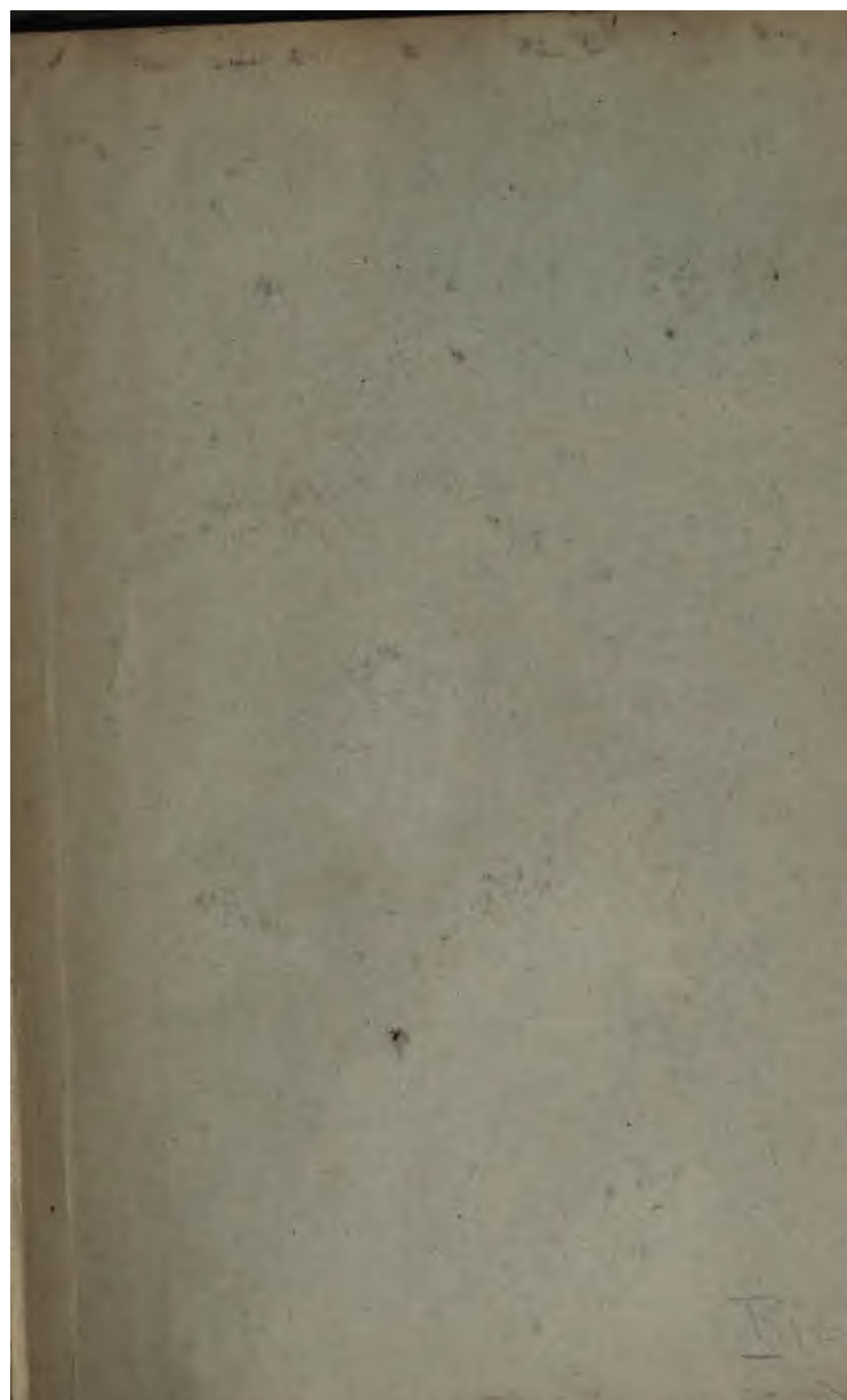
Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>

NTPL RESEARCH LIBRARIES



3 3433 06642062 5





Manufacturers Library

30 Nov 1912

NORTH CAROLINA GEOLOGICAL SURVEY

J. A. HOLMES, STATE GEOLOGIST

BULLETIN No. 13

CLAY DEPOSITS AND CLAY INDUSTRY
IN NORTH CAROLINA

A PRELIMINARY REPORT

BY

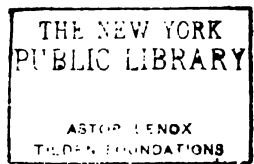
HEINRICH RIES



RALEIGH

GUY V. BARNES, PUBLIC PRINTER
1897





	PAGE
CHAPTER IV.—Geology and geography of North Carolina clay deposits.....	44
Residual clays.....	44
Sedimentary clays.....	46
The North Carolina clay working industry.....	48
CHAPTER V.—Kaolins or china clays.....	50
Character, Mining, Preparation for market.....	50
Distribution of the kaolins.....	50
Mineralogical character of kaolin.....	50
Properties of kaolin.....	51
Mining of kaolin.....	53
Preparation of kaolin for market.....	54
Deposits of kaolin in North Carolina.....	58
Kaolin in Jackson county.....	58
Macon county.....	62
Montgomery county.....	64
Richmond county.....	65
Uses of the North Carolina kaolins.....	68
CHAPTER VI.—Pottery Clays in North Carolina.....	71
The pottery industry.....	71
Requisites of a pottery clay.....	72
Stoneware manufacture.....	73
Pottery industry in Burke county.....	75
Catawba county.....	76
Lincoln county.....	77
Wilkes county.....	78
CHAPTER VII.—Fire-clays and pipe-clays in North Carolina.....	80
Fire-clays.....	80
Fire-clays in Cleveland county.....	81
Guilford county.....	83
Pipe-clays in North Carolina.....	86
Manufacture of sewer pipes and tiles.....	86
Guilford county.....	88
CHAPTER VIII.—Brick-clays and brick manufacturing.....	92
General character of brick-clays.....	92
Requisites of brick-clays.....	93
Methods of brick manufacture.....	94
Soft-mud process.....	94
Stiff-mud process.....	96
Dry-press process.....	99
CHAPTER IX.—Brick-clay deposits in North Carolina.....	102
Brick-clays in Bladen county.....	102
Buncombe county.....	104
Burke county.....	107
Cleveland county.....	108
Cumberland county.....	110
Forsyth county.....	111
Gaston county.....	113

CONTENTS.

5

	PAGE
CHAPTER IX.— <i>Continued.</i>	
Brick-clays in Guilford county.....	114
Halifax county.....	116
Harnett county.....	119
Jackson county.....	121
Martin county.....	122
Mecklenburg county.....	123
Richmond county.....	125
Robeson county.....	126
Rowan county.....	127
Surry county.....	128
Union county.....	129
Wake county.....	130
Wayne county.....	131
Wilkes county.....	134
Wilson county.....	136
Comparison of Wilson and Wayne county clays.....	138
CHAPTER X.—Manufacture of paving-brick.....	139
Requisite character of clay.....	139
Manufacture of paving-brick.....	140
TABLE OF CHEMICAL ANALYSIS OF CLAYS.....	142
TABLE OF PHYSICAL PROPERTIES OF CLAYS.....	146
BIBLIOGRAPHY.....	150
INDEX.....	153

ILLUSTRATIONS.

	PAGE
PLATE I. Pomona Terra Cotta Works, Pomona, N. C.....	Frontispiece.
II. Map showing distribution of geological formations in North Carolina ..	44
III. Fig. 1, Kaolin washing and drying plant, Harris Clay Co.....	56
2, Harris Clay Co.'s mine, showing method of sinking pits in soft kaolin.....	56
IV. Fig. 1, Wooden frame kaolin filter-press.....	58
2, Iron frame kaolin filter-press.....	58
V. Fig. 1, Residual kaolin deposit, Harris Clay Co.'s mine, near Webster...	59
2, Residual clay deposit, Powhatan Clay Mfg. Co., near Grover.....	59
VI. Fig. 1, Press for sewer-pipe, tile, and hollow brick.....	86
2, Chaser mill for tempering clay for sewer-pipe.....	86
VII. Fig. 1, Circular down-draft kiln for tile, etc.....	88
2, Tunnel dryers, used in brick making.....	88
VIII. Fig. 1, Stiff-mud auger end-cut brick machine.....	98
2, Re-pressing brick machine.....	98
IX. Fig. 1, Interior view of a continuous brick-kiln.....	99
2, Exterior view of a continuous brick-kiln.....	99
X. Fig. 1, Up-draft brick-kilns, for burning common brick, at the State Penitentiary, Raleigh, N. C.....	101
2, Down-draft brick-kiln. Eudaly type.....	101
XI. Fig. 1, Black clay along Cape Fear river, at Prospect Hall.....	110
2, Poe Bros'. clay bank, Fayetteville, N. C.....	110
XII. Fig. 1, Brick works of Carter and Shepard, Bethania.....	120
2, Clay deposit in railway cut, Spout Springs, C. F. & Y. V. railroad.	120
 FIG. 1. Pump for removing kaolin from settling vats and forcing it into the presses.	 57
2. Potter's jolly, No. 3.....	74
3. Vaughan sewer-pipe press.....	87
4. Dry-pan crusher.....	97
5. Dry-press brick machine.....	100

BOARD OF MANAGERS.

GOVERNOR D. L. RUSSELL, <i>ex-officio</i> Chairman,	.	.	Raleigh.
CHARLES MCNAMEE,	.	.	Biltmore.
J. TURNER MOREHEAD,	.	.	Leaksville.

STATE GEOLOGIST.

J. A. HOLMES,	.	.	Chapel Hill.
---------------	---	---	--------------

LETTER OF TRANSMITTAL.

To His Excellency, HON. D. L. RUSSELL,
Governor of North Carolina
and Chairman of the Geological Board.

Sir:—I have the honor to transmit as bulletin 13 of the Survey series, a preliminary report on some of the clay deposits and the clay industry in North Carolina, by Dr. Heinrich Ries. This report is not intended as a complete or final discussion of the clay deposits of this State. Their examination has thus far been limited mainly to the regions about towns and railway stations, where the need for information is greatest; but during the next few years it is expected that this work will be extended to all portions of the State where there is a probability of discovering workable deposits of clay or kaolin.

Meanwhile it is thought best to publish, in response to the calls for immediate information, this preliminary report, which I regard as an important contribution to our series of reports on North Carolina resources. I believe it will be well received by the clay workers of the State, and hope that it will prove useful to them.

Yours obediently,

J. A. HOLMES,
State Geologist.

RALEIGH, N. C.,
July 15, 1897.

PREFACE.

The following investigation of the North Carolina clays was undertaken for the purpose of determining (1) the extent, qualities, applicability of the clays occurring within the State; and (2) whether those deposits now being utilized could be used for making other or better products than those that are now being manufactured from them, by varying the mixtures or by the use of different appliances in the manufacture. The field work was carried on during the spring and autumn of 1896, and many of the clay deposits (nearly 100) were visited. Samples were collected from about seventy beds and submitted to chemical and physical investigation.

The chemical work was carried out in a careful and detailed manner by Prof. Chas. Baskerville, of the University of North Carolina. In each case the constituents determined were free and combined silica, alumina, ferric oxide, lime, magnesia, alkalies, moisture, and water. In certain cases determinations were also made of the ferrous oxide, organic matter, sulphur, and titanite oxide. Of the high grade clays, such as the kaolins, a *rational* analysis was made in each case. This, though of great importance, has rarely been done in this country, although it is often carried out abroad. From the rational analysis, as pointed out in the report, it is possible to compute the percentage of clay substance, quartz, and feldspar in the clay, a fact which is of great practical value to the manufacturer, for it gives him an important guide in making up the mixture for the body.

The physical investigations consisted in determining the amount of water required to be added to give a workable mass, the shrinkage in drying and burning of bricklets made from this mud; the color to which the clay burns; the temperatures of incipient fusion, vitrification, and viscosity; the cohesion or tensile strength of the air-dried clay, determined by making briquettes and pulling them apart in a cement testing

machine; the texture of the clay; the slaking in water; and other minor physical characteristics.

The fire tests were carried on in a regenerative gas furnace for temperatures up to 2500 degrees F., but for temperatures above this a Deville furnace was used.

The results of the work show that North Carolina contains an abundance of kaolin of superior quality, as well as clays for the manufacture of stoneware, pressed brick, sewer pipe, and probably paving brick if a mixture of clays is used.

The presence of good clays for the better grades of structural material is of itself a matter of importance, as at present nearly all such wares are brought from other States at considerable cost. While the sedimentary "bottom" clays yield smoother and usually better products than the residual ones, still experiments and practical tests show that the product made from the latter is materially improved by the proper manipulation.

Many of the products are easily accessible, being situated either along navigable rivers or near the intersection of important lines of traffic.

As only a portion of the clay deposits has as yet been examined, this must be regarded as a preliminary report. It is expected that these investigations will be continued until the more promising clay deposits in all parts of the State shall have been examined, and a final and more elaborate report will then be prepared for publication.

Acknowledgments are due to the clay workers of the State for the uniform courtesy with which they have aided the gathering of information for this report.

The American Clay-working Machinery Co., of Bucyrus, O., The Turner, Vaughn and Taylor Co., of Cuyahoga Falls, O., and the Director of the New York State Museum have kindly loaned several of the illustrations for this report.

HEINRICH RIES.

May 9, 1897.

CLAY DEPOSITS AND CLAY INDUSTRY IN NORTH CAROLINA.

BY HEINRICH RIES, Ph. D.

CHAPTER I.

THE ORIGIN OF CLAY.

Forming as it does one of the most abundant materials of the surface of the earth's crust, the enormously extensive application of clay is not to be wondered at. It is to be found almost everywhere, but varies greatly in form, color, and other chemical and physical characters. There are two properties, however, which are more or less constant, and by means of which clay can be generally recognized. These are plasticity when wet, so that any form can be given it by pressure; and the retention of this form when air-dried.

PURE CLAY is composed of the mineral kaolinite, which is a hydrated silicate of alumina, and masses of it are called kaolin. It rarely happens that kaolin is found in a strictly pure state, for more or less foreign mineral matter is usually present, and may form such a large percentage of the kaolin as to completely mask the kaolinite. The latter is known as the clay substance, the foreign minerals being regarded as impurities.

Clay may therefore be defined as a mixture of kaolinite with more or less quartz and other mineral fragments (hydrates, silicates, etc.) possessing usually plasticity when mixed with water, and when subjected to a high heat becoming converted into a hard, rock-like mass.¹

KAOLINITE, the base of all clays, is not an original mineral of the earth's crust, but a secondary one, resulting from the decomposition of feldspars, and possibly sometimes from other aluminous minerals. The feldspars are a group of silicate minerals of rather complex composition, but orthoclase (the common feldspar), which serves as the type of the group, is a compound of silica, alumina, and potash, or in other words, a double silicate of alumina and potash.

The change to kaolinite is brought about by weathering agents of the atmosphere which are continually at work on the minerals of the earth's crust, disintegrating them or converting them into new min-

¹ The flint clays, though nearly pure kaolinite, possess little or no plasticity.

eral compounds. The most active weathering agents are oxygen and carbon dioxide, which by percolating waters are carried into the most remote cracks and crevices of the rocks, and attack the various mineral compounds, simply oxidizing some, decomposing others and carrying part of their elements off as carbonates, while silica may be left behind.

Under the action of these weathering agencies the feldspar is decomposed, the potassium being removed in the form of carbonate, while the silica and alumina remain behind, and with water form the hydrated silicate of alumina or kaolinite, whose composition is expressed by the formula $\text{Al}_2\text{O}_3, 2\text{SiO}_2, 2\text{H}_2\text{O}$; or in the proportions of silica (SiO_2) 46.3%, alumina (Al_2O_3) 39.8%, water (H_2O) 13.9%.

It sometimes happens that the percentage of alumina in clay is over 39.8, as in the case of many of the Missouri flint-clays, and Wheeler has suggested that they may be mixtures of kaolinite and pholerite.¹ The latter is an amorphous variety of the former and contains 45% of alumina.

The purity of a clay as formed will depend largely on the nature of the parent rock or the associations of the feldspar. This mineral frequently occurs in large vein-like masses, in which case its decomposition would yield a bed of nearly pure kaolin, but more frequently it is associated with quartz, or with quartz and mica, etc. When these pegmatite or granite veins decompose, the result is a bed of kaolin with particles of angular quartz and flakes of mica, etc., scattered through it. These mineral impurities can usually be separated by washing.

Beds of kaolin occurring in or very close to their place of origin are known as *residual clays*, and they may represent the purest as well as the most impure forms of clay. The mineral impurities commonly found in residual clays are feldspar, quartz, mica, garnet, hornblende, augite, rutile, etc. Residual clays may form small vein-like masses, or be of enormous extent. The kaolins near Webster and Sylva are examples of the former, the surface clays around Greensboro of the latter.

In the erosion of the earth's surface the residual clay is washed down into the lakes and seas, where it is deposited in the form of a sediment, but with the addition of many impurities.

Clays thus deposited are known as *sedimentary clays*, and are usually far more plastic than the residual clays mentioned above.

The clays of the Cretaceous and Tertiary formations bordering the Atlantic coast are all of sedimentary origin. Shales are simply hardened clays, their rock-like character being due to their having been buried more or less deeply under other sediments formed subsequent

¹ Mo. Geol. Surv., XI, 1897.

to them. On grinding them to a powder and mixing them with water, they become plastic just like other clays.

By metamorphism a shale may lose its chemically combined water, develop a cleavage, and become converted into a slate. It is then no longer possible to develop any plasticity by grinding and mixing with water.

Sedimentary clays may vary widely in their nature, even in the same formation and within small areas. This is due to the variations in direction and velocity of currents in the bodies of water where they were deposited, for the finer clay would only be dropped in quiet water, while where currents existed coarse sand only might be deposited.

Variations in the current at the same point would produce alternating beds of clay and sand, while similar causes might develop large lenses of clay, free from sand or comparatively so, surrounded by coarse sand beds. The kaolin deposits of Aiken, South Carolina, and the black clays exposed in the bluffs at Prospect Hall, North Carolina, are examples of this.

Sedimentary clays may be either soft or hard. In the latter case they are known as shales. Shales, on account of their rock-like condition, are frequently deceptive, yet when ground and mixed with water they possess the same plasticity as soft clay. On account of the fusible impurities which they frequently contain, they are found to be admirably suited to the manufacture of vitrified wares, but in North Carolina no shale deposits have yet been developed which are suitable for the manufacture of clay products.

As clays show all gradations from the purest kaolins to the most impure brick clays, it is hard to draw any sharp lines of division between the kinds of clay used for one purpose or another, and consequently no classification is here given.

As before stated, kaolinite forms the base of all clays, and the rest of the clay is composed chiefly of the two minerals quartz and feldspar. The relative proportion of these three can not be calculated from the ordinary analysis, but if the amount of residue insoluble in sulphuric acid and sodium hydroxide be determined, and this latter analyzed for alumina, potash and soda, it is possible to calculate the amount of clay-base, quartz and feldspar present in the clay. This determination is of special importance in the case of clays used for the manufacture of porcelain, white earthenware, stoneware, tiles, and refractory wares.

The amount of clay-base may vary within wide limits. In a strictly pure kaolin it should theoretically be 100%, but seldom exceeds 90%. On the other hand, it may get as low as 5 or 10 per cent., and in this instance the material would resemble a sand more than clay. The percentage of feldspathic detritus is seldom large.

In kaolins of great purity the clay substance consists of kaolinite, but in impure clays the term is generally taken to mean the finest clay particles, viz., those under $\frac{1}{2500}$ inches diameter. In impure clays the clay substance, which may contain both ferric oxidé and lime, often forms the most plastic portion of the mass.

In the North Carolina clays the variations in clay substance and free sand (quartz and feldspar with some mica) are shown by the following extremes:

Clay substance.

Washed kaolin, Webster (53)	96.81%
Bottom clay, Prospect Hall (12)	85.02%
Crude kaolin, Bosticks Mills (20)	47.14%

Free sand (quartz and feldspar).

Black clay, Prospect Hall (12)	15.05%
Kaolin, Bosticks Mills (20)	52.86%

CHAPTER II.

CHEMICAL PROPERTIES OF CLAY.

The properties of clay are of two kinds, (1) chemical and (2) physical, and the action of clays under heat is not dependent on one class of properties alone, but upon both acting together. Two clays may correspond closely in chemical composition, but differ in their physical properties, and consequently act in a totally different way.

Pure clay, as previously stated, consists of the mineral kaolinite.

This is a white, pearly mineral, crystallizing in the monoclinic system, the crystals presenting the form of small hexagonal plates. Its specific gravity is 2.2 to 2.6, and its hardness is 2 to 2.5. It is naturally white in color, and plastic when wet, but very slightly so. A microscopic examination shows the plates of kaolinite to be collected in little bunches, which if broken apart by grinding increase the plasticity.¹ If kaolin be formed into briquettes of the same shape as those used in testing cement, its tensile strength, as determined by pulling these briquettes apart in a testing machine, is usually 12 to 15 pounds per square inch—a very low amount when compared with the tensile strength of more plastic clays. Kaolinite is practically infusible, as much so as silica or magnesite, but a slight addition of fusible impurities immediately lowers its refractiveness.

IMPURITIES IN CLAY.

The impurities in clay are silica, iron oxides, lime, magnesia, potash, soda, titanitic acid, sulphuric acid, phosphoric acid, manganese oxide and organic matter.² They are generally present in the clay in the form of oxides, silicates, carbonates, sulphates, phosphates, etc. The minerals present in clay containing these impurities may be feldspar, quartz, limonite, mica, garnet, hornblende, augite, calcite, gypsum, talc, etc.

The impurities in a clay will vary in effectiveness according to the quantity present and the combination in which they exist. Thus calcium or alkalis if present as silicates may serve as a most useful flux, whereas if the calcium is present as carbonate it may be very injurious.

The impurities found in clay may be divided into two classes according to their effects: (1) fluxing impurities, and (2) non-fluxing ones.

¹ *The Clays of New Jersey*, N. J. Geol. Survey, 1878. G. H. Cook.

² All of these impurities are seldom present in the same clay.

FLUXING IMPURITIES.

These include alkalies, ferric oxide, lime, magnesia and silica. Their effectiveness or fluxing action is in the order given above; therefore, of two clays having the same physical properties and the same total percentage of fusible impurities, the one might be more fusible than the other on account of having a larger proportion of the more active of the fluxes in its composition. For some purposes it is desirable as well as necessary that the percentage of fluxes should be low, not only for reasons of refractiveness, but also to prevent discoloration of the ware, as when the clay is used for porcelain manufacture. On the other hand, when the clay is to be used for paving brick or sewer-pipe, a high percentage of fluxing impurities is desirable in order to produce a vitrified body. In kaolins the fluxes may be as high as 7%, provided they do not exert a coloring action. Thus some of the most celebrated porcelain kaolins have 35% of feldspar, which means about 5.5% of potash. In fire-clay 4 to 5% is the permissible limit, depending on the physical properties. For paving brick and sewer-pipe the total fluxes may run as high as 16%.

The term fluxing impurities should not be misunderstood. All the substances mentioned below as exerting a fluxing action do not become effective at the same temperature. Thus quartz is a flux at extremely high temperatures, while feldspar acts at a lower temperature, and iron or lime at a lower one still. Furthermore the greater the amount of feldspar present, the lower the temperature at which the quartz and kaolinite act on each other, for the feldspar when fused seems to play the same part that water does in promoting chemical action between two substances which when dry do not act upon each other.

ALKALIES IN CLAY.

The alkalies present in clays may be of two kinds, viz.: the fixed alkalies, potash, soda and lithia, and the volatile alkali, ammonia.

AMMONIA.—This substance is abundant in moist clay, and is absorbed by the latter with great avidity. Indeed, it is responsible to a large extent for the characteristic odor of clay.¹ If the ammonia remained in the clay it would act as a strong flux, but it is rendered harmless for the simple reason that it passes off as a vapor at a temperature considerably below dull redness, or may even volatilize with the moisture in the clay during the early stages of burning.

The fixed alkalies, POTASH, SODA, and LITHIA, will only vaporize at high temperatures, and consequently their effect must be taken into consideration in all stages of the drying and burning. Lithia is of very

¹ F. Senft, *Die Thonsubstanzen*, p. 29.

rare occurrence and only apt to be present in the rare mica, lepidolite; it may therefore be left out of consideration.

Potash and soda are present in almost every clay, from a trace up to nine or ten per cent., with an average of one to three per cent.

The reason for this variation is easily apparent when we consider the composition of pure clay and its derivation. Kaolinite, it will be remembered, contains only silica, alumina and water, whereas orthoclase, the common feldspar, has nearly 17% of alkalies. The presence in the clay, therefore, of varying amounts of undecomposed or even partly altered feldspar would be sufficient to account for the alkalies found in greater or less quantities in the majority of samples analyzed. Aside from the feldspar, the only common rock-forming mineral containing alkalies in abundance is mica. In a few cases potash or soda may be present in the form of soluble salts. We may, therefore, recognize two sources of the alkalies, viz., soluble and insoluble compounds.

SOLUBLE ALKALINE COMPOUNDS.

Soluble alkaline salts are very frequently present in clays, though generally in very small quantities. They may come from the decomposition of feldspar (as in the case of potassium carbonate), or may have been introduced by percolating surface waters. In most regions the soluble alkaline compounds are unimportant and hardly worth attention; but in areas of little rainfall, where evaporation exceeds precipitation, they become concentrated near the surface. These soluble salts may give the manufacturer considerable trouble. Unless decomposed in burning or rendered insoluble in some way, they may form an unsightly white coating on the surface of a burned brick or other product. In a similar manner this crust may interfere with the formation of a salt glaze by preventing the union of the sodium vapors with the silica of the clay, or prevent the glaze adhering to the surface of pottery which is glazed before burning.

Soluble alkaline sulphates are powerful fluxes. They may cause blistering of the ware if the clay is heated sufficiently high to decompose the sulphate and permit the escape of sulphuric acid gases.

In some clays containing sulphate of iron the latter may be decomposed by chemical reactions taking place in the clay and sulphuric acid set free. This acid is apt to attack the alumina of the clay-base, and, if potash, soda or ammonia are present, give rise to potash, soda, or ammonia alum, which can frequently be detected by tasting the clay.

INSOLUBLE ALKALINE COMPOUNDS.

The minerals feldspar and mica forming this class of alkaline salts in clay are among the commonest of the rock-forming minerals. The

feldspars are silicates of alumina and potash, or alumina, lime and soda. Orthoclase is the only species furnishing potash, of which it contains about 17%, while the lime-soda feldspars have from 4 to 12% of soda depending on the species.

The orthoclase is by far the commonest of the feldspars, and next to it in point of abundance come albite and oligoclase, with about 12% and 9% of soda respectively. The species of feldspars present in a clay may have some bearing on its refractiveness, for the soda feldspars are more fusible than the potash ones.

The micas are complex silicates of aluminium with iron, magnesium, and potassium. Muscovite, the commonest species of the group, contains nearly 12% of potash and may at times contain a little soda.

Feldspar is the only serious source of alkalis in clays, however, for the mica is not always present in very large amounts. Mica alone is extremely refractory, being unaffected at a temperature of 2550° F., while feldspar fuses completely at 2300° F.¹

Alkalies, on account of their fluxing properties, especially if in the insoluble form as silicates, are frequently of an advantage, as they serve, in burning, to bind the particles together in a dense, hard body, and permit the ware being burned at a lower temperature. In the manufacture of porcelain, white granite and C. C. ware (cream-colored ware), the alkalies for fluxing are added to the body in the form of feldspar, provided the kaolin does not already contain a sufficient amount of this material. Much feldspar is mined in this country for potters' use, all of it being the potash feldspar.

So far as is known, the alkalies exert no coloring influence on the burned ware, although if an excess of feldspar be added to a white burning kaolin, the latter may exhibit a yellowish tint when burned.

In the North Carolina clays the combined alkalis (potash and soda) vary from .29% in clay from Spout Springs to 4.62% in brick clay from Wilkesboro. The average is 1.50 to 2.5%. The washed kaolins usually contain under one per cent. The pottery clays of North Carolina have from 0.68 to 2.82%.

COMPOUNDS OF IRON IN CLAY.

Aside from being a flux, iron oxide is also the great natural coloring agent of clays in both their raw and burned state. The mineral compounds which may serve as the sources of iron oxides in clays are as follows:

Silicates: Mica, hornblende, garnet, etc.

Oxides: Limonite, hematite, magnetite.

Sulphides: Pyrite, marcasite.

Sulphates: Melanterite.

Carbonates: Siderite.

¹ G. Vogt, Bull. de la Soc. Chim. de Paris; and Chem. News, 1890, p. 315.

The silicate mineral, mica, is missing in very few clays. Of the oxides, limonite and hematite are frequent impurities, and are often introduced from the surface by percolating waters, or may result from the decomposition of minerals, such as garnet. This fact is noticeable in some of the less pure portions of the kaolin beds at Webster, North Carolina. The iron oxides color the raw clay various shades of red and yellow. Pyrite is frequently present in clays, especially in many stoneware and fire-clays, its yellow, glittering metallic particles being easily recognizable. When disseminated through the clay in small grains it may be difficult to separate except by careful washing; but when occurring in lumps, popularly known as "sulphur balls," it is much easier to extract. If the finely disseminated pyrite remained in the clay, it would be found after burning that the clay was dotted with fused spots of silicate of iron. Many of the first speckled brick so extensively used at the present time were made in this manner.

The pyrite may readily become oxidized to the soluble sulphate of iron, which, if present in sufficiently large amounts, imparts an inky taste to the clay. Pyrite being such a strong flux, the addition of $1\frac{1}{2}$ to 2% by weight, according to Wipplinger,¹ may exert a noticeable effect in the increase of its fusibility.

In all the classes of iron compounds mentioned above, the iron is present in one or two conditions, viz. as a ferrous or ferric salt; and the fusibility of the clay depends somewhat on this condition, ferrous salts being more fusible than ferric salts. In burning any clay the ferrous salt will be changed to the ferric salt, provided the action of the fire is oxidizing. If the fire exerts a reducing action, the same clay will, under these conditions, fuse at a lower temperature.

Ferric silicate may be an original mineral impurity of the clay, but many ferric compounds in clays result from the oxidation of ferrous carbonate or ferrous hydrate in clay which has been introduced in solution. The presence of ferric hydrate in clay increases its absorptive power for gases and solutions. On burning, the hydrate is of course converted into an oxide.

If treated to an oxidizing fire, the presence of ferrous salts need not therefore be considered, provided the heat is raised high enough to oxidize them. The rapidity with which the temperature is raised is important, for if the heat is raised too quickly the outer portion of the clay may shrink and become dense before the air has had time to permeate the clay and oxidize the iron in the centre of the body. This is the cause of black cores sometimes seen in bricks whose surface is red. This rapid heating may also bring about a differential shrinkage between the interior and exterior of the brick and cause cracking.

¹ *Keramik*, p. 26.

Unburned clays may be yellow, blue, brown, red or gray in color, depending on the relative amounts of ferrous and ferric salts present.

The same variety of shades and colors is produced in burning. Ferrous oxide (FeO) alone produces a green color when burned, while ferric oxide (Fe_2O_3) alone may give a purple, and mixtures of the two may produce yellow, cherry-red, violet, blue and black,¹ a fact which is of the greatest importance to manufacturers of unglazed wares. The more intense the heat the deeper the color produced by the iron.

Seger² found that combinations of ferric oxide with silica produced a yellow or red color, while similar compounds of the ferrous salt showed blue and green.

The black coloration by iron produced by hard firing is often to be seen on breaking open the arch bricks of a brick kiln. The surface of these bricks may get black, due to the dust and ashes of the fire sticking to it.

The bleaching of the iron color by the presence of lime is to be seen in many calcareous clays, as described under lime. It may sometimes happen, however, that a calcareous clay when burned does not become buff, but shows a red surface, as if there were no lime present to neutralize the iron color.

In such an instance as found by Seger, the core of the brick may show the expected buff color. This was brought about by the sulphuric acid vapors from the fuel uniting with the lime of the clay to form calcium sulphate, thus preventing its union with the ferric oxide.

The percentage of ferric oxide permissible or desirable in a clay depends on the quality of the latter. Kaolins, to be used in the manufacture of white ware, should have under 1% if possible, although many with 1.5% produce excellent results. A greater percentage might be present, provided there was also present three times as much lime to neutralize its color.

If a kaolin has enough ferric oxide to produce a faint yellowish tinge when burned, by burning it in a reducing atmosphere the color will be bluish, and will be far less noticeable. The reduction is accomplished by letting less air into the kiln, and the production of a smoky fire.

The North Carolina washed kaolins contain from .28% to 1.86%; the unwashed, 1.14% to 1.86%; the pottery clays from 2.88% to 5.48%.

The total range of ferric oxide in the seventy-three samples of North Carolina clays which were tested was from .28% to 11.79%, with an average of 1.5% to 5%.

LIME IN CLAYS.

Lime is a common detrimental or fluxing impurity of most medium or low grade clays. It may be present in one of three conditions, viz.:

¹ *Keramik*, p. 258.

² *Notizblatt*, 1874, p. 16.

- a. As a silicate, such as in the feldspars.
- b. As a simple carbonate, limestone or calcite, or in the form of a double carbonate, as dolomite.
- c. As a sulphate, such as gypsum.

The first two of these are primary mineral constituents of the clay, the third is of secondary origin and results from chemical action taking place in the clay.

The presence of lime as a silicate in clay is probably the form in which it usually occurs, especially if the clay has been derived wholly or in part from a region of feldspathic rocks. The common feldspar, orthoclase, contains no lime, so that it probably comes from the lime-soda feldspars. There are other silicates containing lime, but their presence is usually more difficult to prove with certainty.

When present as a silicate, lime acts as a flux, but it is less liable to exert a decolorizing action on the clay, by the formation of a double silicate of iron and lime, except at higher temperatures.

Calcium carbonate is very common in clays which have been derived in part from limestone areas, or it may result from the decomposition of lime-bearing feldspars. Its presence may be usually determined by treating the clay with muriatic acid, which produces effervescence if more than 4 or 5% of calcium carbonate is present.

Lime if present in the form of lumps or pebbles is very injurious, and should be removed by screening or washing. Finely divided lime though, if not present in too large amounts, may be harmless. Clays with 20 to 25% of calcium carbonate may be used for common or even pressed bricks, and also for earthenware. In the latter case the same clay can often be utilized for glazing the pottery, requiring only the addition of some fluxes.

EFFECT ON THE BRICK OF CALCIUM CARBONATE IN CLAY.

When occurring as carbonate in clay, lime becomes far more injurious. If the clay is underburned, the calcium carbonate will be simply broken up into carbon dioxide and lime. The former escapes, but the lime, on the cooling of the brick, slakes, that is to say, it absorbs water from the air, and swells, thus frequently bursting the brick.

If, however, the clay is thoroughly burned, the calcium carbonate after being decomposed unites with any free silicate that may be present and forms silicate of lime or probably also silicate of lime and alumina. If iron oxide is present, the lime takes it also into combination and thereby destroys its coloring action, giving a buff product instead of a red one, as would be the case if the iron oxide remained free. It should also be stated, however, that a low percentage of iron oxide in the clay without the presence of lime will also give a buff-colored ware. This is the case with many stoneware clays.

In high-grade clays large amounts of lime do not have to be considered, for such materials cannot be used, but in the manufacture of building brick, or pressed brick, terra-cotta, etc., it is frequently necessary to use a clay containing large percentages of lime, either from necessity or to obtain a cream-colored ware. It therefore becomes a matter of importance to know how much lime is permissible in a clay for this purpose. In general, it may be said that a good brick can be made from a clay containing 20 to 25% of calcium carbonate, provided it is evenly distributed through the clay and in as finely a divided state as possible.

Some clays contain lime in angular fragments or pebbles, which can be frequently removed by screening.

Aside from lowering the fusibility of a clay to a marked extent, lime also exerts a powerful effect on its shrinkage.

Seger¹ found that calcareous or marly clays required usually only 20 to 24% of water to convert them from a dry condition into a workable paste, whereas other clays needed 28 to 35% of water to accomplish the same change. Furthermore, as calcareous clays lost not only combined water but also carbon dioxide in burning, the bricks were the more apt to be light and porous, and this increased with the amount of lime present. They also shrink much less than other clays up to the points of incipient fusion. This low shrinkage may become zero, and the brick swell instead of shrinking. He also found that the difference between the points of incipient fusion and viscosity was so small that it was extremely difficult to bring a kiln of bricks made from calcareous clay to vitrification without melting a large number.

Seger claims that the presence of calcium carbonate and ferric oxide in the proportions of 3:1 is sufficient to produce a buff color.

Many clays contain calcium in the form of gypsum, the hydrated calcium sulphate. It generally originates from the action on calcium carbonate by sulphuric acid obtained by the oxidation and leaching of pyrite in the clay. Gypsum frequently discloses its presence by the formation in the clay of crystals or masses of its transparent variety, selenite. It also not uncommonly occurs in masses of parallel fibres filling cracks or cavities in the clay.

It serves as a flux, but may do considerable damage in burning by its disintegration, the sulphuric acid thus set free causing in its escape blisters on the surface of the wares.

There is another method by which lime may be introduced into clay, and that is absorption. This may occur when a clay deposit rests on a limestone or marl formation, and the lime being taken into solution by the percolating waters is soaked up by the clay. In this event the lower layers of the clay would be more calcareous than the upper ones.

¹ *Gesammelte Schrift*, p. 265.

Few of the North Carolina clays are very calcareous. Out of the seventy-three samples examined the lime varied from .1% in the clay at Prospect Hall to 2.55% in Kirkpatrick's clay at Greensboro. This latter is exceptionally high, for most of the North Carolina clays contain under 1%.

Its action, therefore, in all of the samples tested amounts to very little.

Marly clays are known to occur in the coastal plain formation near the coast, but none of these have been tested.

MAGNESIA IN CLAYS.

Magnesia rarely occurs in clays in the same quantity as lime; in fact, it rarely exceeds 2%. In the North Carolina clays, however, of which samples were examined it seldom exceeds .75%, and is generally present in about the same quantity as the lime.

Magnesia may be derived from the same classes of compounds as lime, viz. silicates, carbonates and sulphates.

The silicates are probably by far the most abundant form of its occurrence in clay and are represented by the minerals mica, chlorite, and hornblende (all scaly minerals) containing respectively 20-25%, 15-25%, and 15% of magnesia. The mica scales may be prominent in many clays, and chlorite scales, if very abundant, might even tend to color the clay green. Hornblende is mostly present in clays derived from rocks of a very basic composition (that is, with a low silica percentage), and the same may be said of pyroxene, which, however, is less common than the hornblende.

Dolomite, the double calcium-magnesium carbonate, has been mentioned under the description of lime (p. 21).

Magnesium sulphate, or epsom salts, occurs sparingly in clays. It is mostly to be found in those clays where sulphuric acid, set free by the decomposition of pyrite, has attacked magnesium carbonates. The presence of magnesium sulphate can frequently be detected by the bitter taste which it imparts to the clay.

As far as the effects of magnesia are concerned with the chemical properties of clay, they are probably the same as lime. This, however, can only be stated with a reasonable amount of certainty, for magnesia is generally present in such small amounts that its actual effect cannot be detected.

NON-FLUXING IMPURITIES.

These include silica, titanite oxide, organic matter, and water. Both silica and titanite oxide at high temperatures are fluxes.

SILICA IN CLAYS.

Chemical analysis distinguishes two classes of silica, viz. (1) that combined with aluminium in kaolinite, and (2) sand. The latter includes quartz, and silica in combinations with various bases as in feldspar and mica (excluding kaolinite). The two kinds of silica included in this second class are insoluble in sulphuric acid and sodium hydroxide. If this residue be further analyzed, it is possible to calculate the amount of silica present as quartz and that contained in the clay in the form of feldspar or mica. This is frequently an important matter, for the condition of the silica may influence the fusibility of the clay to a marked degree.

Free silica or quartz is present in all clays in variable amounts. Cook¹ found a minimum of 0.2 of one per cent., and gives 5% as the average in the Woodbridge fire-clays. Wheeler² gives the minimum as 0.5 of one per cent. in the flint clays, and the sand as 20 to 43% in the St. Louis fire-clays, and 20 to 50% in the Loess clays.

Twenty-seven samples of Alabama clays contained from 5 to 50% of insoluble residue, mostly quartz.³

Seventy North Carolina clays had from 15.05 to 70.43% insoluble residue; while of three samples of which a rational analysis was run the percentage of sand was from 24.55 to 56.58%, and the quartz percentage in these ran from 16.58 to 49.06%, and the feldspathic detritus from 7.52 to 16.05%.

Free silica is considered by Bischof⁴ to exert a fluxing action at high temperatures, that is, over 2800° F.

The most important effects of free silica and sand are directed towards the physical properties of clay. They lessen the plasticity, diminish the tensile strength and also the shrinkage. If silica is present in excess and in grains of large size, it may cause the clay to expand in burning. Quartz in fine grains lessens the shrinkage less than when present in large ones.

TITANIUM IN CLAYS.

Titanium is probably of widespread occurrence in clay, though never present in great quantity; it may be derived from rutile (TiO_2) or ilmenite (titaniferous iron ore). It was formerly looked upon as a rare element and a non-detrimental impurity, but this idea of its rarity has resulted from the fact that it is usually overlooked in chemical analyses. According to Seger, it is often present in clay slates and bauxites. Its effect on the refractiveness of a clay has always been misunderstood, although its action was considered similar to silica.

¹ N. J. Clay Rept., 1878, p. 213.

² Forthcoming Bulletin of Alabama Geological Survey.

³ Mo. Geol. Surv., XI, p. 54.

⁴ *Die Feuerfesten Thone*, 1896.

Although the determination of titanium in clay requires no difficult methods, it has, as a rule, not been determined in the chemical analyses of clay except when specially desired.

In order to determine definitely what the effect of titanium was, Seger and Cramer¹ took a sample of Zettlitz kaolin (which has 98.5% of clay substance) and mixed two samples of it with respectively 5% and 10% of silica, and two other samples of the kaolin with respectively 6.65% and 13.3% of titanitic oxide. These samples were molded into pyramids, which were heated to a temperature above the fusing point of wrought iron with the following results:

1. Pure Zettlitz kaolin burned to a white, sharp-edged, dense body.
2. 100 pts. kaolin and 10% silica burned white.
3. " " " " 5% " " "
4. " " " " 6.65% titanitic oxide softened in heating and showed a blue fracture.
5. " " " " 13.3% titanitic acid fused to a deep blue enamel.

It will therefore be seen that titanium acts as a flux at lower temperatures than silica, and calls to mind the fact that the blue color given to some stoneware clays by hard firing may not be due always to iron oxide.

ORGANIC MATTER IN CLAYS.

This is commonly noticed in many clays by the black color which it imparts to them, but the clay may also be colored brown or blue from the same cause.

The organic matter generally consists of finely divided pieces of plant tissue, or large pieces of stems and leaves, which settled in the clay during its deposition. All surface clays contain plant roots in their upper layers, but these do not always exert a coloring effect.

Clays colored by organic matter, and containing no iron, burn white as the plant tissue burns off at a bright redness, but if such a clay is heated too quickly the surface of the piece becomes dense before all of the organic matter has had time to escape from the interior, and the latter remains dark colored. The presence of iron may be masked by organic matter, so that the clay burns red, as is the case with the clays from Prospect Hall, on the Cape Fear river. Organic matter is seldom determined separately in chemical analysis, but its quantity may often be judged approximately from the relation between loss on ignition and alumina.

Organic matter exercises the important property of increasing the plasticity, but all clays having organic matter are not necessarily plastic, for the presence of much sand may render such a clay very lean, like the Prospect Hall clays.

¹ *Ges. Schr.*, p. 411.

In the weathering of clays, organic material, by its oxidation and consequent evolution of carbonic acid, helps to break up the clay.

WATER IN CLAYS.

The water in clay is of two kinds:

1. Hygroscopic water or moisture.
2. Chemically combined water.

MOISTURE.—This may be as low as .5% in air-dried clays or reach 30%-40% in those freshly taken from the bank. In the air-dried specimens of the North Carolina clays it ranged from .08% to 3.07% in the kaolins, .45% to 4.50% in the sedimentary clays, and .95% to 1.90% in the residual brick clays.

Air-drying expels most of the moisture in a clay, and this is accompanied by a shrinkage which, in 70 samples tested from North Carolina, ranged from 2% to 13.3%. Sandy, coarse-grained clays usually show the least shrinkage, but some of the fine-grained ones may act in a similar manner. The amount of water which a dry clay needs in order to develop an easily worked paste varies from 12%-20% in lean ones and 25%-35% for fat clays. The samples of North Carolina clays tested required from 16%-40%. The more water that a clay absorbs the more it has to part with in drying and the greater will be the shrinkage. If the clay is fine-grained, rapid drying may cause it to split from the active disengagement of steam.

In the manufacture of clay products the moisture is expelled by exposing the ware to the sun or drying it in heated tunnels. The last portions of moisture are driven off in the early stages of burning, known as water smoking, during which time abundant white vapors can be seen issuing from the kiln.

COMBINED WATER is present in every clay. In pure kaolin there is nearly 14% of it. In other clays the percentage varies with the amount of clay-base and hydrates present. In the North Carolina clays the loss on ignition (which practically amounted to combined water, those containing organic matter being left out) varied from 4.04% to 13.40% in the washed kaolins, 5.98% to 9.00% in the residual clays, and 4.17% to 11.08% in the sedimentary ones.

Combined water is driven off at a low red heat, and when this takes place the clay begins to suffer an additional loss in volume or shrinkage.

It is a curious fact that while the amount of combined water does not seem to stand in any close relation to the plasticity of a clay, nevertheless, when once driven off, the clay can no longer be rendered plastic by the addition of water. The fire shrinkage in the North Carolina clays varied from 2%-12%.

METHODS EMPLOYED IN MAKING CLAY ANALYSES.

The following brief statement of the methods employed in making the analyses of clays for this report has been prepared by Dr. Charles Baskerville, by whom the analyses were made:

Moisture.—Two grams are heated in a platinum crucible at 100° C. until they show a constant weight. The loss is reported as moisture.

Loss on Ignition (combined water, and sometimes organic matter, etc.).—The crucible and clay are heated with a blast lamp until there is no further loss in weight.

Alkalies.—This same portion of clay, which has been used for determining moisture and loss, is treated with concentrated sulphuric and hydrofluoric acids until it is completely decomposed. The acids are evaporated off by heating upon the sand-bath. The cooled crucible is washed out with boiling water to which several drops of hydrochloric acid have been added. The solution after being made up to about five hundred cubic centimetres is boiled, one-half gram ammonium oxalate added and made alkaline with ammonium hydroxide; the boiling is continued until but a faint odor of ammonia remains. The precipitate is allowed to settle and is separated from the liquid by filtering and washed three times with boiling water. The filtrate is evaporated to dryness and ignited to drive off ammonium salts. The residue is treated with five cubic centimetres of boiling water, two or three cubic centimetres of saturated ammonium carbonate solution are added and the whole is filtered into a weighed crucible or dish. The precipitate is washed three or four times with boiling water and the filtrate evaporated to dryness. Five drops of sulphuric acid are added to the residue and then the crucible or dish is brought to a red heat, cooled in a desiccator, and the alkalies are weighed as sulphates.

To separate the alkalies, the sulphates are dissolved in hot water, acidified with hydrochloric acid, sufficient platinum chloride added to convert both the sodium and potassium salts into double chlorides; the liquid is evaporated to a syrup upon a water-bath, eighty per cent. alcohol added, and filtered through a Gooch crucible or upon a tared filter paper. The precipitate is thoroughly washed with eighty per cent. alcohol, dried at 100° C. and weighed; the potassium oxide is calculated from the double chloride of potassium and platinum.

When magnesium was present to as much as one-half of one per cent. the magnesium hydroxide was precipitated with barium hydroxide solution, and the barium in turn removed by ammonium carbonate. When the amount of magnesium was less than the amount named, this portion of the ordinary process was not regarded as necessary.

Silica.—Two grams of clay are mixed with ten grams of sodium carbonate and one-half gram of potassium nitrate and brought to a calm

fusion in a platinum crucible over the blast lamp. The melt removed from the crucible is treated with an excess of hydrochloric acid and evaporated in a casserole to dryness upon a water-bath, and heated in an air-bath at 110° C. until all the hydrochloric acid is driven off. Dilute hydrochloric acid is added to the casserole now, and the solution brought to boiling and rapidly filtered. The silica is washed thoroughly with boiling water and then ignited in a platinum crucible, weighed, and moistened with concentrated sulphuric acid. Hydrofluoric acid is cautiously added until all the silica has disappeared. The solution is evaporated to dryness upon a sand-bath, ignited and weighed. The difference in weight is silica.

Iron Sesquioxide.—The filtrate from the silica is divided into equal portions. To one portion in a reducing flask is added metallic zinc and sulphuric acid. After reduction and filtration to free the liquid from undissolved zinc and carbon, the iron is determined by titration with a standard solution of potassium permanganate.

Aluminium Oxide.—To the second portion, which must be brought to boiling, ammonium hydroxide is added in slight excess, the boiling continued from two to five minutes, the precipitate allowed to settle and then caught upon the filter, all the chlorides being washed out with boiling water. The precipitate is ignited and weighed as a mixture of aluminium oxide and iron sesquioxide. The amount of iron sesquioxide already found is taken from this and the remainder reported as alumina.

Calcium Oxide.—The filtrate from the precipitate of iron and aluminium hydroxides is concentrated to about two hundred cubic centimetres, and the calcium precipitated in a hot solution by adding one gram of ammonium oxalate. The precipitate is allowed to settle during twelve hours, filtered and washed with hot water, ignited and weighed as calcium oxide. When the calcium is present in notable amounts, the oxide is converted into the sulphate and weighed as such.

Magnesium Oxide.—The filtrate from the calcium oxalate precipitate is concentrated to about one hundred cubic centimetres, cooled and the magnesium precipitated by means of hydrogen disodium phosphate in a strongly alkaline solution, made so by adding ten cubic centimetres of ammonium hydroxide (0.90 sp. gr.). The magnesium ammonium phosphate, after standing over night, is caught upon an ashless filter, washed with water containing at least five per cent. ammonium hydroxide, burned and weighed as magnesium pyrophosphate.

The *insoluble residue* is determined by digesting two grams of clay with twenty cubic centimetres of dilute sulphuric acid for six or eight hours on a sand-bath, the excess of acid being finally driven off. One cubic centimetre of concentrated hydrochloric acid is now added and

boiling water. The insoluble portion is filtered off, and after being thoroughly washed with boiling water is digested in fifteen cubic centimetres of boiling sodium hydroxide of ten per cent. strength. Twenty-five cubic centimetres of hot water are added and the solution filtered through the same filter paper, the residue being washed five or six times with boiling water. The residue is now treated with hydrochloric acid in the same manner and washed upon the filter paper, and free from hydrochloric acid, is burned and weighed as insoluble residue.

A portion of this is treated as the original clay for silica, aluminium oxide, and iron oxide. Another portion is used for the determination of the alkalies in the insoluble residue.

Titanic Oxide.—One-half gram clay is fused with five grams potassium bisulphate and one gram sodium fluoride in a spacious platinum crucible. The melt is dissolved in five per cent. sulphuric acid. Hydrogen dioxide is added to an aliquot part and the tint compared with that obtained from a standard solution of titanium sulphate.

Sulphur (total present).—The sulphur is determined by fusing one-half gram of clay with a mixture of sodium carbonate, five parts, and potassium nitrate, one part. The melt is brought into solution with hydrochloric acid. The silica is separated by evaporation, heating resolution, and subsequent filtration. Hydrochloric acid is added to the filtrate to at least five per cent. and the sulphuric acid is precipitated by adding barium chloride in sufficient excess, all solutions being boiling hot. The barium sulphate is filtered off and washed with hot water, burned and weighed as such.

Ferrous Oxide is determined by fusing one-half gram clay with five grams sodium carbonate, the clay being well covered with the carbonate, the top being upon the crucible. The melt is dissolved in a mixture of dilute hydrochloric and sulphuric acids in an atmosphere of carbon dioxide. The ferrous iron is determined at once by titration with a standard potassium permanganate solution.

The *rational analysis* is made from the results obtained by the chemical analysis in the following way: The alumina found in the portion insoluble in sulphuric acid and sodium hydroxide is multiplied by 3.51. This factor has been found to represent the average ratio between alumina and silica in orthoclase feldspar; therefore the product just obtained would represent the amount of silica that would be present in undecomposed feldspar. The sum of this silica with the alumina, ferric oxide and alkalies equals the "feldspathic detritus." The difference between silica as calculated for feldspar and the total silica in the insoluble portion represents the "quartz" or "free sand." The difference between that portion of the sample insoluble in sulphuric acid and sodium hydroxide and the total represents the "clay sub-

stance." The method of analysis used to determine the mineralogical character of the clay is called the *rational* method, and when carried out in its simplest form, determines the amount of clay substance or kaolinite, quartz, and feldspar present in the clay. If carried out more completely it enables us to calculate the amount of calcite or limestone (calcium carbonate), iron oxide and even mica in the clay.

THE RATIONAL ANALYSIS OF CLAY.

In the ordinary or *ultimate* quantitative analysis of clay the latter is regarded as being composed of a given number of elements or oxides of them, in given amounts, but gives no clue as to the condition in which these substances exist, viz., whether they are present as oxides, silicates, carbonates, etc., a point which it is often of the greatest importance to know. Thus, as pointed out under calcium (Chemical Properties of Clay), if this substance is present as a carbonate it may be extremely injurious, but if combined with silica in the form of feldspar it is beneficial, serving as a binding material (p. 21). Or, again, the ultimate analysis does not point out the condition of the silica, whether present as quartz (serving to lessen the shrinkage) or as a constituent of feldspar (serving as a flux). A high percentage of total silica in an ultimate analysis may be caused by an excess of feldspar and not always by quartz.

The inferences which may be drawn from the ultimate analysis of a clay are:

1. It may be said in general that the greater the amount of ferric oxide in a clay the deeper red it will burn at any given temperature. Small percentages of ferric oxide will only color the clay yellow.
2. We can see from the ultimate analysis whether there is sufficient lime present to counteract the effect of the ferric oxide.
3. It is possible to gain an approximate idea of the fusibility of the clay from the total fluxes present, and also to see whether it is the weaker or more powerful fluxes that are present.
4. A very high silica percentage generally indicates a sandy clay.
5. Clays high in alumina and combined water as a rule shrink considerably in burning.

There are, however, many physical properties which the ultimate analysis does not explain, because they are dependent largely on the mineralogical composition.

It frequently happens that two clays show very close chemical composition, but act entirely unlike, and the explanation is almost self-evident, viz., that the elements present in both clays are differently combined.

The following table of analyses illustrates this, viz.:

1. That clays with the same ultimate composition may show a different rational composition (see analyses *a* and *b* below).

2. That clays may agree in both their ultimate and rational analysis (see *b* and *c* below), but this is not very frequent:

	<i>a.</i>	<i>b.</i>	<i>c.</i>
Silica	47.60	46.61	46.82
Alumina	34.00	36.47	38.49
Ferric oxide.....	1.30	2.81	1.09
Lime	trace	.14	.....
Magnesia	.50	.....	trace
Alkalies	3.00	1.44	1.40
Loss on ignition	13.60	12.80	12.86
Total	100.00	100.17	100.66
Clay substance	88.34	96.08	96.55
Quartz	8.95	1.93	2.30
Feldspar	2.73	1.99	1.15
	100.02	100.00	100.00

The practical bearing of the rational analysis has thus far been chiefly for those branches of the clay-working industry using mostly materials of considerable purity, as in the manufacture of porcelain, white earthenware, fire-bricks, glassspots and encaustic tiles; and its importance lies in the fact that two bodies having the same rational composition will usually act pretty much alike. That is to say, that other things being equal, they will, for instance, usually have the same shrinkage in burning.

In the manufacture of porcelain the body generally consists of a mixture of kaolin, quartz and feldspar. Suppose that the mixture has 60 parts of feldspar and 200 parts of kaolin, the latter having the rational composition of the Wests Mill, N. C., material, viz.:

Clay substance, 83.39; quartz, 14.98; feldspar, 1.58.

This would give us a mixture with rational composition of:

Clay substance, 60.32; quartz, 11.40; feldspar, 24.30.

If now for the Wests Mill kaolin we desired to substitute that from near Bostick having:

Clay substance, 54.30; quartz, 43.85; feldspar, 1.82,

and used the same amount as we did of the Wests Mills material, we should get a mixture having:

Clay substance, 41.77; quartz, 33.31; feldspar, 20.30.

This mixture having less feldspar and clay substance, but more quartz, would probably show less plasticity and less shrinkage. Knowing, however, the rational composition of the Bostick kaolin, it is perfectly easy to add it in such proportions as will keep our mixture of the same composition.

In the manufacture of tiles, where one clay body is pressed on to another, it is highly essential that the two should have the same shrinkage to prevent cracking during the burning and cooling.

Experiments tend to show that if the two bodies have the same rational composition their shrinkages will be about the same, provided there is not much difference in the coarseness of their grain. In porcelain and white earthenware manufacture the clays are ground so fine that this point does not come into consideration.

A rational analysis has been made of all the North Carolina kaolins tested, and in the other clays the insoluble residue (quartz and feldspar combined) was determined.

CHAPTER III.

PHYSICAL PROPERTIES OF CLAY.

These are fully as important as the chemical ones, and sometimes more so. In Germany the labors of Seger, Bischof, Olschewsky and others have brought forth the significance which the physical properties of clays have, and in this country the work of Orton and Wheeler has corroborated them in many details.

Chemical analysis alone cannot be used as a basis of comparison, but the physical characters must also be taken into consideration.

While the list of physical properties may be made of considerable length, there are a number which are of special importance and will be considered herewith. These are plasticity, fusibility, shrinkage, tensile strength, slaking, absorption, density.

PLASTICITY IN CLAYS.

This is one of the most important properties of clays, for it permits their being molded into any desired form, which they subsequently retain.

Plasticity in clays is exceedingly variable. Those possessing little plasticity are called "lean," while those which are highly plastic are known as "fat" clays.

The cause of plasticity was for a long time supposed to be directly connected with the hydrated silicate of alumina, or kaolinite, and clays high in kaolinite were said to be very plastic and vice versa. This is plainly not so, as any series of clays tested will demonstrate.

Pure or nearly pure kaolins are very lean, while clays low in alumina may be highly plastic. This may be shown by a few examples drawn from the North Carolina clays tested, mentioning first that the tensile strength of a clay (as will be explained later) is closely related to its plasticity.

The examples to illustrate this point are as follows:

	Per cent. of Alumina.	Tensile strength in pounds per sq. in.	
		Average.	Maximum.
Lower clay, Roanoke Rapids (3)	16.09	206	218
Washed kaolin (53)	40.61	20	22
Clay, Spout Springs (17)	32.51	24	29

Prof. G. H. Cook¹ considered that plasticity was due to a plate struc-

¹ N. J. Geol. Survey, Rept. on Clays, 1878.

ture present in the clay, the plates sliding over each other and thus permitting mobility of the mass without cracking. As kaolinite is practically the only plate-like mineral omnipresent in the clay, the simple plate theory does not seem entirely sufficient.

Olschewsky¹ was probably the first to suggest that the plasticity and cohesion of a clay were dependent on the interlocking of the clay particles and kaolinite plates, and in this connection used the briquette method of testing the plasticity or rather obtaining a numerical expression for it, by determining the tensile strength of the air-dried clay.

The more recent experiments of W. Aleksiejew and P. A. Cremiatschenski on the Russian clays² show that plasticity is not only due to the interlocking of the clay particles, but also varies with the fineness of the grain, the extreme coarse and fine ones both having less plasticity.

In this country Wheeler's work on the Missouri clays has substantiated these views.³

Experiments by the writer on the Alabama clays⁴ corroborate these results still further, and the tests of the North Carolina ones also point in the same direction. The clays southeast of Spout Springs, for example, which are very fine-grained, plainly show the lessening effect on the tensile strength.

Whether, however, the greatest tensile strength depends on the presence of particles of certain size, or a mixture of different sizes, and, if so, within what limits these sizes must be, is still to be determined.

Plasticity, whatever may be its exact cause, is an important property from a commercial standpoint, for it facilitates the molding or burning of the wares without cracking.

The amount of water required to develop the maximum plasticity varies. If too little is added, the clay cracks in molding and is stiff and hard to work. If too much water is used, the paste becomes soft and retains its shape with difficulty. Lean clays usually require less water to produce a workable paste than fat ones.

TENSILE STRENGTH OF CLAYS.

To state that the plasticity of a clay is lean, fair, good, or high is necessarily only approximate and unsatisfactory, and a method by which the degree of plasticity can be expressed accurately is much to be preferred.

Various methods for testing the plasticity of a clay have been devised, but as most of them are practically useless, if for no other reason than

¹ *Töpf. u. Zieg.*, 1882, No. 29.

² *Zap. imp. russk. techn. obschtsch.*, 1896, XXX, pt. 6-7.

³ *Mo. Geol. Surv.*, XI, 1897, p. 102.

⁴ *The Clay-working Industry in 1896*, 18 *Ann. Rept. U. S. Geol. Surv.*, pt. V, p. 1129.

that they are largely influenced by the personal equation, their discussion need not be gone into here, and any one desiring to look them up is referred to C. Bischof's work, "Die Feuerfesten Thone."

Two methods, however, approach the requirements:

The first consists in forming the clay into a bar of known section and then noting the load required to crossbreak it.¹

The second, devised by Olschewsky,² consists in molding the clay into briquettes of the same shape as those used in testing cement, allowing them to air-dry, and then pulling them apart in a cement testing machine, noting the number of pounds pull required. Before breaking, the cross-section of the briquette must be carefully measured and the tensile strength per square inch calculated, as the clay shrinks in drying. This is a perfectly rational method and supposes that as plasticity is dependent on the interlocking of the particles, the tensile strength will naturally stand in direct relation to it. Even though it is not yet certain that this is the cause of plasticity, still it is certain that with increase in plasticity there is a rise in the tensile strength.

In the North Carolina clays the tensile strength varied from 5 lbs. per sq. in. in a Webster kaolin to 220 lbs. per sq. in. in a brick clay from Greensboro.

The residual clays tested were all of low tensile strength.

The clays were all ground to pass through a 30-mesh sieve before being molded into the briquettes.

SHRINKAGE OF CLAYS.

The variable shrinkage of clays in drying has already been mentioned in the discussion of water in clays. The amount of shrinkage depends somewhat on the amount of water absorbed or the porosity of the clays. But coarse-grained clays may absorb much water and yet shrink comparatively little. Having larger pores, they will permit the water to escape more rapidly, and hence can often be dried quicker than fine-grained ones, from which the water on account of the smallness of the pores cannot escape so quickly.

If fine-grained clays are dried rapidly, the surface shrinks quicker than the interior, and cracking may ensue, especially if the clay has a low tensile strength.

The air shrinkage begins as soon as the clay is molded and set out in the sun or put in a hot tunnel to dry, and continues until the moisture is driven off.

The fire shrinkage generally commences when the combined water begins to pass off, or about 1200° F. It varies just as the air shrinkage did.

¹ P. Jochem, *Zeitsch. der Verein deutsch. Ing.*, 1895.

² *Töpf. Zeit.*, 1882, No. 26.

In the North Carolina clays the fire shrinkage was from 2-12%, with an average of 4-6%.

The fire shrinkage is influenced by several conditions, viz. amount of combined water, organic matter, and sand. The fire shrinkage increases with the amount of organic matter and combined water in the clay. Sand diminishes the shrinkage. Lime has the same tendency and may even make the clay swell a little. Clays containing a large amount of feldspar, will, instead of showing a steady shrinkage up to the temperature of complete vitrification or sintering, often exhibit a temporary increase of volume when the fusing point of the feldspar (about 2300° F.) is reached.

Between the points at which the moisture has ceased coming off and that at which the combined water begins to escape, the clay shrinks little or none at all. Consequently in firing a clay the heat can be raised rapidly between these two points, but above and below them it must proceed slowly to prevent cracking the ware.

FUSIBILITY OF CLAYS.

In the heating of a clay, or subjecting it to a gradually increasing temperature, it not only shrinks but begins to harden. After the moisture has been driven off the clay bears some handling and is moderately hard, but can be scratched by the finger-nail.

Accompanying the second shrinkage of the clay, beginning at a dull red heat, there comes an increase in hardness and density, and at a temperature of from 1500° to 2100° F., depending on the clay, it becomes very dense, the individual particles are barely recognizable, and the clay cannot be scratched with a knife. It is still porous, however. This is the point of *incipient fusion*. With an increase in the temperature of from 50° to 200° F., depending on the clay, an additional amount of shrinkage occurs. The clay becomes hard, dense, impervious, the particles are no longer recognizable, and the maximum shrinkage has been attained. This is the point of *vitrification* or sintering. With a further similar rise in temperature the clay becomes *viscous* or flows.

These three stages are not sharply marked, but with a little practice the eye can detect the condition which the burned clay has reached. With few exceptions, the point of vitrification seems to be midway between incipient fusion and viscosity. The difference in temperature between these two points varies from 75°-100° F. in calcareous clays, up to 400° or more in the purer ones. Indeed, the majority of clays show a difference of 300°-400° F. between incipient fusion and viscosity.

The practical value of this property is at once apparent, for many clays require to be heated to vitrification, and the greater the margin between this point and viscosity the better, for a kiln cannot be managed within very narrow limits of temperature.

TEMPERATURE AT WHICH CLAY FUSES.

It may be said in general that, other things being equal, the fusibility of a clay will increase with the amount of fluxes.

This is only to be regarded as an approximate statement, for all the fluxing impurities do not act with the same intensity.

If the fluxes are the same, a fine-grained clay will fuse at a lower temperature than a coarse-grained one, because in a clay with fine grain the particles are closer together, and can interact better chemically when they become softened by the heat. This fact may be brought out by a comparison of the pipe-clay from the first pit at Pomona and that at Spout Springs.

The former is coarse-grained, and, though containing 5.10% of fluxes, only vitrifies at 2250° F., while the latter, with only 3.81% total fluxes, vitrifies at 2150° because it is very fine-grained.

Several attempts have been made to express the relative fusibilities of clays numerically, but none of them are wholly satisfactory, as they do not give a series of numbers expressing the relative fusibilities of different clays, which stand in the same order as the fusibilities themselves.

Until this can be done such formulæ have no definite value, and, in any case, it is more satisfactory to know the actual temperature of fusion of a clay than to express it in relative terms.

Bischof¹ assumed that refractoriness of a clay is directly as the square of the alumina and inversely as the silica and fluxes. He therefore deduced the formula in which F. Q. stands for "Refractory quotient."

$$F. Q. = \frac{(Al_2O_3)^2}{SiO_2 \times RO}.$$

This only holds good for comparing clays of the same fineness. When there is a variation in this the formula no longer holds good.

Wheeler^{*} has suggested the formula

$$F. F. = \frac{N}{D + D' + C}$$

in which F.F. is called the Fusibility Factor.

N = sum of non-detrimentals, or silica, alumina, titanica acid, water, moisture and carbonic acid.

D = sum of detrimental impurities, or iron, lime, magnesia, alkalies, sulphuric acid, sulphur, etc.

D' = sum of alkalies which Wheeler supposes to have twice the fluxing value.

The formula without C was not much more regular in its results than Bischof's.

¹ *Die Feuerfesten Thone*, p. 71, 1876.

^{*} *Eng. and Min. Jour.*, LVII., 1894, p. 224.

fusing points. Seger's series were numbered from 1 to 20, and the difference between their fusing points is 36° F. A later series, introduced by Cramer, runs from .01 to .022 with a difference of 54° F. between their fusing points. The higher numbers of the cones have also been extended up to 36.

These pyramids have been recently recalibrated, and therefore the fusing points and composition of the different numbers are given herewith, being taken from the recently issued circular of the Thonindustrie Laboratorium, in Berlin, where these cones were first made.

FUSION TEMPERATURES BASED UPON RECENT RECALCULATIONS FOR SEGER'S PYRAMIDS.

No. of Cone.	Composition.			Fusion Point.	
				Cent.	Fahr.
022	0.5 Na ₂ O } 0.5 PbO }	.....	{ 2 SiO ₂ 1 B ₂ O ₃	590	1094
021	0.5 Na ₂ O } 0.5 PbO }	0.1 Al ₂ O ₃	{ 2.2 SiO ₂ 1 B ₂ O ₃	620	1148
020	0.5 Na ₂ O } 0.5 PbO }	0.2 Al ₂ O ₃	{ 2.4 SiO ₂ 1 B ₂ O ₃	650	1202
019	0.5 Na ₂ O } 0.5 PbO }	0.3 Al ₂ O ₃	{ 2.6 SiO ₂ 1 B ₂ O ₃	680	1256
018	0.5 Na ₂ O } 0.5 PbO }	0.4 Al ₂ O ₃	{ 2.8 SiO ₂ 1 B ₂ O ₃	710	1310
017	0.5 Na ₂ O } 0.5 PbO }	0.5 Al ₂ O ₃	{ 3.0 SiO ₂ 1 B ₂ O ₃	740	1364
016	0.5 Na ₂ O } 0.5 PbO }	0.55 Al ₂ O ₃	{ 3.1 SiO ₂ 1 B ₂ O ₃	770	1418
015	0.5 Na ₂ O } 0.5 PbO }	0.6 Al ₂ O ₃	{ 3.2 SiO ₂ 1 B ₂ O ₃	800	1472
014	0.5 Na ₂ O } 0.5 PbO }	0.65 Al ₂ O ₃	{ 3.3 SiO ₂ 1 B ₂ O ₃	830	1526
013	0.5 Na ₂ O } 0.5 PbO }	0.7 Al ₂ O ₃	{ 3.4 SiO ₂ 1 B ₂ O ₃	860	1580
012	0.5 Na ₂ O } 0.5 PbO }	0.75 Al ₂ O ₃	{ 3.5 SiO ₂ 1 B ₂ O ₃	890	1634
011	0.5 Na ₂ O } 0.5 PbO }	0.8 Al ₂ O ₃	{ 3.6 SiO ₂ 1 B ₂ O ₃	920	1688
010	0.3 K ₂ O } 0.7 CaO }	0.2 Fe ₂ O ₃ 0.3 Al ₂ O ₃	{ 3.50 SiO ₂ 0.50 B ₂ O ₃	950	1742
09	0.3 K ₂ O } 0.7 CaO }	0.2 Fe ₂ O ₃ 0.3 Al ₂ O ₃	{ 3.55 SiO ₂ 0.45 B ₂ O ₃	970	1778
08	0.3 K ₂ O } 0.7 CaO }	0.2 Fe ₂ O ₃ 0.3 Al ₂ O ₃	{ 3.60 SiO ₂ 0.40 B ₂ O ₃	990	1814
07	0.3 K ₂ O } 0.7 CaO }	0.2 Fe ₂ O ₃ 0.2 Al ₂ O ₃	{ 3.65 SiO ₂ 0.35 B ₂ O ₃	1010	1850
06	0.3 K ₂ O } 0.7 CaO }	0.2 Fe ₂ O ₃ 0.3 Al ₂ O ₃	{ 3.70 SiO ₂ 0.30 B ₂ O ₃	1030	1886
05	0.3 K ₂ O } 0.7 CaO }	0.2 Fe ₂ O ₃ 0.3 Al ₂ O ₃	{ 3.75 SiO ₂ 0.25 B ₂ O ₃	1050	1922
04	0.3 K ₂ O } 0.7 CaO }	0.2 Fe ₂ O ₃ 0.3 Al ₂ O ₃	{ 3.80 SiO ₂ 0.20 B ₂ O ₃	1070	1958
03	0.3 K ₂ O } 0.7 CaO }	0.2 Fe ₂ O ₃ 0.3 Al ₂ O ₃	{ 3.85 SiO ₂ 0.15 B ₂ O ₃	1090	1994

CLAY DEPOSITS IN NORTH CAROLINA.

FUSION TEMPERATURES, ETC.—Continued.

No. of Cone.	Composition.			Fusion Point.	
				Cent.	Fahr.
02	0.3 K ₂ O } 0.7 CaO }	0.3 Fe ₂ O ₃ } 0.3 Al ₂ O ₃ }	{ 3.90 SiO ₂ 0.10 B ₂ O ₃	1110	2030
01	0.3 K ₂ O } 0.7 CaO }	0.3 Fe ₂ O ₃ } 0.3 Al ₂ O ₃ }	{ 3.95 SiO ₂ 0.05 B ₂ O ₃	1130	2066
1	0.3 K ₂ O } 0.7 CaO }	0.2 Fe ₂ O ₃ } 0.3 Al ₂ O ₃ }	{ 4 SiO ₂	1150	2102
2	0.3 K ₂ O } 0.7 CaO }	0.2 Fe ₂ O ₃ } 0.4 Al ₂ O ₃ }	{ 4 SiO ₂	1170	2138
3	0.3 K ₂ O } 0.7 CaO }	0.05 Fe ₂ O ₃ } 0.45 Al ₂ O ₃ }	{ 4 SiO ₂	1190	2174
4	0.3 K ₂ O } 0.7 CaO }	0.5 Al ₂ O ₃ 4SiO ₂		1210	2210
5	0.3 K ₂ O } 0.7 CaO }	0.5 Al ₂ O ₃ 5SiO ₂		1230	2246
6	0.3 K ₂ O } 0.7 CaO }	0.6 Al ₂ O ₃ 6SiO ₂		1250	2282
7	0.3 K ₂ O } 0.7 CaO }	0.7 Al ₂ O ₃ 7SiO ₂		1270	2318
8	0.3 K ₂ O } 0.7 CaO }	0.8 Al ₂ O ₃ 8SiO ₂		1290	2354
9	0.3 K ₂ O } 0.7 CaO }	0.9 Al ₂ O ₃ 9SiO ₂		1310	2390
10	0.3 K ₂ O } 0.7 CaO }	1.0 Al ₂ O ₃ 10SiO ₂		1330	2426
11	0.3 K ₂ O } 0.7 CaO }	1.2 Al ₂ O ₃ 12SiO ₂		1350	2462
12	0.3 K ₂ O } 0.7 CaO }	1.4 Al ₂ O ₃ 14SiO ₂		1370	2498
13	0.3 K ₂ O } 0.7 CaO }	1.6 Al ₂ O ₃ 16SiO ₂		1390	2534
14	0.3 K ₂ O } 0.7 CaO }	1.8 Al ₂ O ₃ 18SiO ₂		1410	2570
15	0.3 K ₂ O } 0.7 CaO }	2.1 Al ₂ O ₃ 21SiO ₂		1430	2606
16	0.3 K ₂ O } 0.7 CaO }	2.4 Al ₂ O ₃ 24SiO ₂		1450	2642
17	0.3 K ₂ O } 0.7 CaO }	2.7 Al ₂ O ₃ 27SiO ₂		1470	2678
18	0.3 K ₂ O } 0.7 CaO }	3.1 Al ₂ O ₃ 31SiO ₂		1490	2714
19	0.3 K ₂ O } 0.7 CaO }	3.5 Al ₂ O ₃ 35SiO ₂		1510	2750
20	0.3 K ₂ O } 0.7 CaO }	3.9 Al ₂ O ₃ 39SiO ₂		1530	2786
21	0.3 K ₂ O } 0.7 CaO }	4.4 Al ₂ O ₃ 44SiO ₂		1550	2822
22	0.3 K ₂ O } 0.7 CaO }	4.9 Al ₂ O ₃ 49SiO ₂		1570	2858
23	0.3 K ₂ O } 0.7 CaO }	5.4 Al ₂ O ₃ 54SiO ₂		1590	2894
24	0.3 K ₂ O } 0.7 CaO }	6.0 Al ₂ O ₃ 60SiO ₂		1610	2930
25	0.3 K ₂ O } 0.7 CaO }	6.6 Al ₂ O ₃ 66SiO ₂		1630	2966

FUSION TEMPERATURES, ETC.—Continued.

No. of Cone.	Composition.		Fusion Point.	
			Cent.	Fahr.
26	0.3 K ₂ O } 0.7 CaO }	7.2 Al ₂ O ₃ .72SiO ₂	1650	3002
27	0.3 K ₂ O } 0.7 CaO }	2.0 Al ₂ O ₃ .200SiO ₂	1670	3038
28	Al ₂ O ₃ .108SiO ₂		1690	3074
29	Al ₂ O ₃ .88SiO ₂		1710	3110
30	Al ₂ O ₃ .68SiO ₂		1730	3146
31	Al ₂ O ₃ .58SiO ₂		1750	3182
32	Al ₂ O ₃ .48SiO ₂		1770	3218
33	Al ₂ O ₃ .38SiO ₂		1790	3254
34	Al ₂ O ₃ .2.58SiO ₂		1810	3290
35	Al ₂ O ₃ .28SiO ₂		1830	3326
36	Al ₂ O ₃ .2SiO ₂		1850	3362

When these pyramids are placed in a kiln or furnace they begin to soften as the temperature is raised, and as it approaches their fusion point the cones bend over until the tip is as low as the base. When this occurs the temperature at which they fuse is considered to be reached.

If it is therefore stated that a clay vitrifies at cone 5, it means that the amount of heat required to make cone 5 bend over is sufficient to vitrify the clay. In this report it has not been thought advisable to use this method but to give the actual temperatures. Comparisons can be easily made by looking up the number of the cone in the foregoing table.

These cones are accurate to within 25°, which is entirely sufficient for practical purposes. In actual use the cones are set in the kiln at a point where they can be watched through a peep-hole but will not receive the direct touch of the flames from the fuel.

It is well to put two or more cones in so that warning can be had of the approach of the desired temperature.

In order to determine the temperature of a kiln, several cones of separated numbers are put in, as, for example, .07, 1, and 5. Suppose that .07 and 1 are bent over in burning, but 5 remains unaltered. The temperature of the kiln was therefore between 1 and 5. The next time 2, 3 and 4 are put in. 2 and 3 may be fused, but 4 remains unaffected. The temperature therefore reached the fusing point of 3, or 2174° F. If the cones up to about No. 2 are heated too quickly, they are apt to swell up, and prevent themselves bending over.

Seeger's cones are extensively used in Europe, and in America their application is extending. Their one great advantage is that they indicate not the actual temperature, but rather its action. Thus cone No. 1 does not bend over as soon as the temperature of 2102° F. is reached, but only when this temperature has penetrated the cone. It is not advisable to

use a cone a second time, in case it has not bent over in a previous burning. Such cones are apt to bend at a lower temperature.

In porcelain manufacture, cones of the same composition as the glaze on the ware are sometimes used.

These cones can be obtained for about one cent each from Prof. E. Orton, Jr., Ohio State University, Columbus, O.

SLAKING OF CLAYS.

When a lump of clay is placed in water it begins to slake or break up in a more or less characteristic manner, depending on the nature of the clay. Some homogeneous clays split into a number of angular fragments, others into scaly particles, while still others break up completely into their component grains. The rapidity of slaking varies, depending largely on the density and toughness of the clays. Some clays slake completely to pieces in two or three minutes, while others may lie in water for an hour or two and remain totally unaffected.

This property is of practical importance in two ways. In washing kaolins or stoneware clays it is desirable that they should fall apart quickly when thrown into water, and thereby permit a quicker and more thorough separation of the impurities.

Slaking is also of importance in tempering clays, for the easier they break up the easier and more thoroughly will they become mixed in the pugmill.

MINOR PHYSICAL PROPERTIES OF CLAYS.

The other physical properties of clay, such as absorption, fineness of grain, taste, color, have been mentioned in connection with other properties and need be but briefly referred to here.

ABSORPTION OF WATER.

The absorption of clays varies of course, some taking up a large amount of water, which they give off again in drying, with the risk of **cracking** the clay unless dried very slowly. The presence of organic matter, ferric hydrate and ammonia may increase the absorptive power. The residual clays common throughout the western half of the State often absorb a large amount of water, without showing much plasticity. They are coarse-grained and very porous, and show the property not uncommon to many clays, in that they become more plastic as water is added up to a certain limit, but a slight addition over this causes the clay to become soft and decrease rapidly in plasticity.

TEXTURE OF CLAYS.

Fineness of grain, as already mentioned, has an important bearing on the fusibility of clays. It also diminishes the tensile strength, and,

with few exceptions, requires the clay to be slowly dried, and in burning to be slowly heated at first. In porcelain manufacture the particles of clay must be of extreme fineness, and this has often to be brought about by grinding.

TASTE OF CLAYS.

Tasting a clay will often give a clue to the presence of soluble salts, such as sulphates of iron or magnesia, which may impart a bitter, inky taste to the clay. The presence of grit may also be detected by grinding a lump of the clay between the teeth.

COLOR OF CLAYS.

The color of a clay serves only as an indication of its quality within very wide limits.

Many high-grade clays which burn white are in their original or green state colored black by the presence of a small per cent of organic matter. The latter, however, may mask the presence of iron, as in those from Prospect Hall, which burn to a deep red.

Iron may color a clay green, yellow, red, gray, brown or black, depending on the condition of its compound, whether ferrous or ferric. In surface clays it frequently exists in the ferric condition as limonite or hematite, and imparts a brilliant yellow or red to the clay. Not unfrequently the upper part of a clay bank is yellow or red, due to the presence of abundant ferric oxide, while the lower portion of it may be blue or gray from the iron being less oxidized. Many kaolins with a very small percentage of ferric oxide burn white in oxidizing fire, but in reducing fire burn gray, due to a reduction of the iron from the ferric to the ferrous condition.

The colors imparted by the different constituents have been mentioned under the chemical properties. It should be remembered that in case the clay does not burn to a color which the analysis would indicate, that it may be due to the union of the elements in the clay with substances in the fire gases of the kiln. Many coals contain sulphur. In burning the sulphuric acid gases are apt to unite with the lime or other substances in the clay, with formation of sulphates.

DENSITY OF CLAYS.

The specific gravity of a clay varies with its mineralogical composition, and may run from about 1.75 to 2.60. Thus far it is not known of itself to have any practical value. In the summary of tests at the end of the report will be found the specific gravities of the North Carolina clays here described, determined by Prof. F. P. Venable.

CHAPTER IV.

GEOLOGY AND GEOGRAPHY OF NORTH CAROLINA CLAY DEPOSITS.

The clay deposits of North Carolina belong to two types, residual and sedimentary, which, with their varieties, may be grouped as follows:

- Residual:—Kaolins; fire-clays; and impure clays.
- Sedimentary: { Coastal plain clays, of Cretaceous or Tertiary age.
Sedimentary surface clays (for brick and pottery), mainly along
the streams and low-lands, in the Piedmont plateau and mountain counties.

The accompanying outline map (Plate II) indicates the general distribution of the geological formations in the State, except that no attempt is made to separate those of the coastal plain region.

RESIDUAL CLAYS.

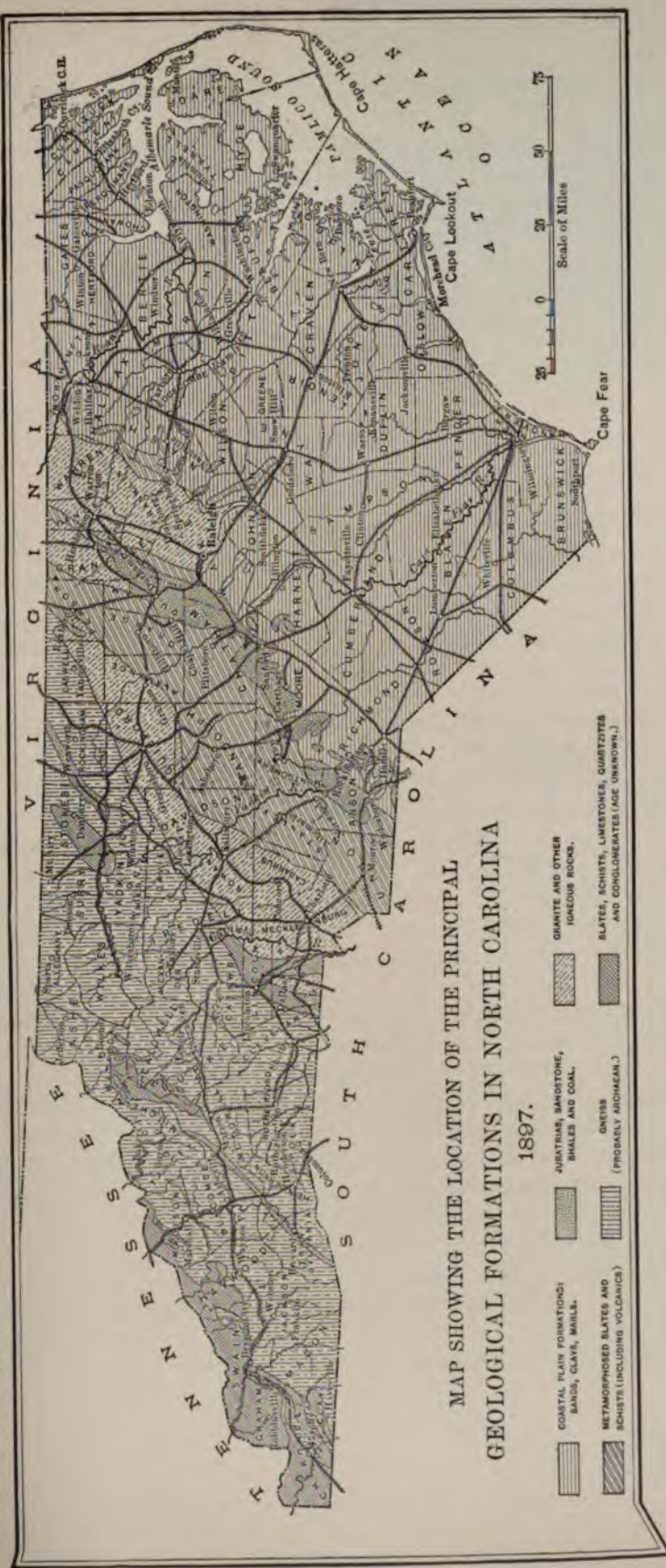
These in general are to be found in any portion of the western half of the State, that being the area underlain by the granitic, gneissic, and schistose rocks from which they have originated by the decay *in situ*, as explained under the origin of clay.

The eastern border of this area of crystalline rocks passes through the counties of Halifax, Franklin, Wake, Chatham, Moore, Richmond, and Anson.

West of this line, which passes near Weldon, Raleigh and Rockingham, we find the residual clays forming an almost universal mantle over the surface. They are generally coarse-grained, red, brown or yellow sticky clays, frequently of a lean character. Their thickness varies from three to twenty or more feet, depending on the depth to which disintegration of the rock has taken place and the amount of erosion of the surface that has occurred. In general, we may expect to find them of less thickness on the steep slopes than on the gentler ones or level areas.

It not unfrequently happens that the clay has been little disturbed, and the banded structure of the gneiss or schist from which it originated may still be seen extending upward into the clay. As quartz decomposes more slowly than most rock-forming minerals, the veins of this material are also to be seen at times traversing the clay.

Residual clays commonly contain many angular grains and fragments of undecomposed or only partially decomposed mineral matter, and the relative amount of this depends on the extent of the rotting of the rock.





The brickmakers are very prone to use these materials on account of their sandy nature, their lean character making them much easier to work by hand; at the same time their porous nature produces a porous, weak brick unless properly burned, and at the smaller brickyards the burning is seldom carried far enough.

The composition of two of these impure residual clays is given below:

Composition of Residual Clays.

	Dean's Yard, Greensboro.	Greensboro Brk. & Tile Co.
Moisture	1.90	1.64
Silica	59.27	56.81
Alumina	22.31	20.62
Ferric oxide	6.69	6.13
Lime	.25	.65
Magnesia	.13	.58
Alkalies	.90	4.47
Water (loss on ignition)	9.00	8.60
Total	100.45	99.50
Free sand	33.35	40.65
Fluxes	7.97	11.83

The residual fire-clays found at Pomona and Grover are coarse-grained, sandy clays of a semi-refractory nature, with much intermixed quartz and mica. At times these two mineral impurities may become so abundant that the portions of the vein holding them have to be avoided in mining.

As these semi-refractory clay deposits have been but little worked thus far, not very much can be said of their extent. Vein formations such as they result from are often apt to be of a pocket-like nature, but at times are very extensive, so that they should be well exploited before much mining is done.

These residual clays are sometimes found such a short distance from their point of origin that they still practically possess their residual characteristics of leanness, coarseness, angularity of fragments, etc.

The kaolins, which also come under this head, are of the greatest commercial value. They result from the decomposition of feldspar or granite veins, so abundant in the crystalline area of North Carolina. In width they vary from a few inches to 300 feet, and the kaolin extends from the surface to a depth of 60 to 120 feet, depending on the extent to which the feldspar has altered. Below this the fresh or partially altered rock is met. In their unaltered state these veins may serve as sources of feldspar or quartz, which, when of sufficient purity, are available for potters' use.

The kaolin deposits at Webster, N. C., have been worked for a num-

ber of years to supply the potteries at Trenton, N. J., and East Liverpool, Ohio. The field work and laboratory tests carried on in connection with the preparation of this report indicate additional ones of a very promising nature.

SEDIMENTARY CLAYS.

The coastal plain deposits of North Carolina furnish the most extensive beds of clay to be found within the State. They have been classed as belonging to the Potomac (lower Cretaceous), Tertiary, and post-Tertiary (Columbia) formations.¹

The former are best exposed along the Cape Fear river below Fayetteville, and consist of dark-colored clays, at times very sandy and frequently containing an abundance of organic matter.

The clay usually forms large lenses, and sometimes, by the increase of sand, passes into sand beds. One of the best exposures of these black Potomac clays is at Prospect Hall, 21 miles below Fayetteville; but they are exposed also in many of the river bluffs from 10 to 60 miles below Fayetteville (p. 102).

The Eocene deposits are best exposed along the western border of the coastal plain region in Moore and Harnett counties, lying near or at the summits of the sand hills and ridges. Their thickness varies from 5 to 15 feet, or possibly more, and there usually is but little (2 to 6 feet) of sandy overburden. The best known exposures of these are on the Sprunt lands, 2 to 3 miles north of Spout Springs, and 2 miles southeast of Southern Pines on the Seaboard Air Line Railway.

There are good exposures of clay in the cuts of the Cape Fear and Yadkin Valley R. R. between Spout Springs and Fayetteville, the age of which is not certain, though they are probably Eocene or Cretaceous.

The composition of these latter clays (see table at the end of report) might lead one to assign a refractory character to them, but their extreme fineness of grain causes them to fuse at comparatively low temperatures. Their smoothness is marked, and they might be used for other purposes.

Finely laminated clays of various colors are also to be found exposed in railway cuts and river bluffs in many parts of the coastal plain region, in some places associated with tertiary marls, and elsewhere overlying them. Along the western border of the coastal plain region, both in the river bluffs and on the divides between the streams, as are to be seen at intervals along the Atlantic Coast Line R. R. from Weldon to a few miles south of Fayetteville, are beds of finely laminated clays varying in color from yellowish to nearly black, and often mottled, which are believed to be a part of the Lafayette formation. None

¹ J. A. Holmes. "The Kaolin and Clay Deposits of North Carolina," *Trans. Amer. Inst. Min. Eng.* XXV, p. 929, 1896.

of these clays has yet been fully tested, but the results of their examination will be described in a later report.

There is also to be found in the terraces bordering the larger streams for some miles above and below where they pass from the hill country into the coastal plain region, a series of red and brown loams, which, near Weldon, Goldsboro and Fayetteville, in North Carolina, and at as many points similarly located in other Southern States, have been found to make good brick when properly manipulated. These "brick loams," as they have been designated, are of still more recent origin than the laminated Lafayette clays mentioned above, and they are classed with the youngest of our extensive geological formations, that known as the Columbia.

Many of the rivers farther inland, as they pass across the hill country, and even in the mountain region, are often bordered by considerable stretches of terrace which are underlain by brick or pottery clays, often of excellent quality.

The more sandy clays under these terraces are generally to be found close to the river, while the finer grained and smoother ones have been deposited nearer shore at the edge of the terrace, and when there are several terraces they are usually found under the upper one.

Such terraces are abundant along the Catawba river near Morganton and Mount Holly; along the Yadkin river, especially at Wilkesboro and Elkin; along the Clarke river (south fork of Catawba river) at Lincolnton, where clay to supply some fifty potters is dug.

It is from these terrace deposits of recent geologic age that some of the best clays in the State are to be obtained. In depth they vary from five to ten feet, and as some of these river valleys supply the lines of railroad with an easy passage through the mountain regions, the clays are well located for shipment either in their burned or unburned condition.

These river clays are also well developed along the French Broad river near Asheville; and at Biltmore they have produced excellent and extremely encouraging results.

It not uncommonly happens that the river terrace is formed on the slope of some hill covered by coarse-grained, lean, residual clays, and by the gradual creep of the soil the residual material moves down on to the sedimentary clay underlying the terrace. Such conditions are not uncommon, and at first sight the section of this kind exposed in a clay bank presents a rather peculiar appearance.

As mentioned above, the sedimentary clays are also well developed around Wilson, Goldsboro and Fayetteville.

With proper treatment, as will be mentioned later, these clays are capable of excellent results, and yet by careless methods the product that is sometimes produced is not fit to use.

Just as much care should be taken in the manufacture of brick as in white ware. There is, unfortunately, too much disposition to regard a brick as so many cubic inches of burned clay that must be able to stick together and little more.

The omnipresence of residual brick clays in the South has had an injurious effect on the clay-working industry, for when a large cotton mill or other building is erected the contractor generally digs up the nearest residual clay soil, the most siliceous he can find, and even then sand is sometimes added to it to permit its mixing with the minimum amount of labor.

This clayey sand is then molded by hand and hurriedly burned in small scove kilns. The great amount of sand naturally tends to make a porous brick, and burning the kiln barely to incipient fusion, and never much beyond, prevents the clay from reaching its maximum shrinkage. The result is a porous, soft brick.

The sedimentary clays generally make a smoother, denser brick, and one which burns at a lower temperature, but the residual brick clays are frequently capable of good results if properly handled.

Clays for making good common and pressed brick are of as much importance in North Carolina as stoneware clays and kaolins, for practically all the pressed brick now used in the State are shipped from other States.

THE NORTH CAROLINA CLAY-WORKING INDUSTRY.

The products at present manufactured in North Carolina include stoneware, earthenware, fire-brick, sewer-pipe, flue-linings, drain-tile and building brick.

Stoneware is manufactured by a number of small potters located chiefly in the western part of the State. The clays used burn to a dense hard body at moderate temperature, 2100° F., but the ware has a rough surface due to the glazing material, which contains much grit. The same potters make red earthenware articles to a limited extent. With the available clays there is room for much improvement in the character of the ware.

Fire-brick are manufactured at Pomona, Guilford county, Emma, Buncombe county, and Grover, Cleveland county. In each case the clays are coarse-grained, sandy ones, with much quartz and mica. Those at Grover especially would probably make a very good grade of refractory material, but their application has thus far been limited.

Sewer-pipe and flue-linings are only made at Pomona, Guilford county, but the factory located at that place is turning out a very good product, and it has recently been much enlarged.

Common brick are manufactured at many localities throughout the

State, but pressed brick have not passed beyond the experimental stage; although many of the clays are admirably adapted for this purpose, as those near Asheville, Buncombe county, at Wilkesboro, Wilkes county, around Goldsboro, Wayne county, and Raleigh, Wake county.

Many of these towns are at the intersection of several lines of railroad, so that the product could be easily shipped.

In visiting the various localities for the collection of samples for analysis and physical tests, this point has been borne in mind, and the areas most accessible have been especially examined.

CHAPTER V.

KAOLINS OR CHINA CLAYS.

CHARACTER, MINING, PREPARATION FOR MARKET.

North Carolina is one of the important producers of kaolin used by the manufacturers of white granite, C. C. (cream-colored) ware, and porcelain, at Trenton, East Liverpool and other localities in the United States, and the material produced stands second to none thus far mined in this country.

All of the North Carolina kaolins thus far discovered are of a residual nature, that is, the material is found at the point where it originated. They have resulted from the decay of veins of pure feldspar, pegmatite or granite, and vary in their initial impurity according to the number of foreign minerals which occurred in the vein from which they were formed.

DISTRIBUTION OF THE KAOLINS.

Knowing thus the nature of their origin, it is possible to predict approximately the limits within which they can occur. As the feldspar and granite veins are generally found cutting the gneisses, granites or hornblende and mica schists, the kaolin deposits can occur in any part of the central or western parts of the State, this being the area underlain by the crystalline rocks. Large deposits have thus far been recorded from Montgomery, Richmond, Cleveland, Burke, Jackson, and Macon counties.

MINERALOGICAL CHARACTER OF KAOLIN.

The kaolin from most of these veins is a white, dense, soapy substance, soft and easily picked out. Through this may be scattered scales of mica, garnet, quartz, etc. The mica is generally fresh in appearance unless it is an iron-bearing species. The garnet is almost invariably decomposed and forms rusty stains which can generally be eliminated in washing. The quartz is practically always undecomposed and in angular fragments. Its condition determines the necessity of its separation; that is to say, if the quartz were extremely fine its presence would be harmless. If the vein was originally a coarsely crystalline mass of quartz and feldspar, the former remains in such large fragments that it is necessary to eliminate it by washing; but if the quartz and

feldspar were intimately associated in a finely granular mixture, then the quartz may be scattered through the kaolin in the form of a fine siliceous powder, and if there are no other impurities with it, the quartz can be left in the kaolin.

Indeed, it sometimes happens that there is so much finely divided quartz present that it is impossible to separate all of it by washing. This is the case with the kaolin from Troy.

Depending, therefore, on the character of the quartz, the washed kaolin from different localities may show a very variable amount of clay substances.

In the case of the Webster kaolin the quartz forms a large mass in the centre of the vein, and is left standing while the kaolin is mined away on either side.

In Plate V, facing page 59, fig. 2 shows a bed of residual clay near Grover, and fig. 1 an extensive vein of residual kaolin near Webster.

PROPERTIES OF KAOLIN.

Kaolin of good quality is pure white when washed and dried, but often gray when wet. The purest North Carolina kaolin, and also other American kaolins, show on microscopic examination bunched and also isolated scales of kaolinite, plates and scales of white mica, grains of quartz, and apparently feldspar grains.

The plasticity of kaolin is usually very lean, although some crude kaolins are appreciably plastic to the feel. The tensile strength is always low, and in the North Carolina kaolins varies on the average from 5 to 20 lbs. per square inch. Most kaolins absorb considerable water in being worked into a plastic paste. They burn to a white body when little iron is present, and the hardness and density vary with the degree of temperature to which they are subjected, and also with the amount of quartz and feldspar which they contain. In the manufacture of china the kaolin is mixed with ball clay to give the mass plasticity, and feldspar to act as a flux. Quartz is also added to prevent excessive shrinkage. It is in this connection that the value of a *rational* analysis is felt.

The rational analysis considers a clay as being made up of quartz, feldspar, and kaolinite or clay substance, and shows the amount of each present in the clay. If now the potter changes from the kaolin he has been using to one from another locality, it will be possible for him, if he has a rational analysis of this new clay, to determine without endless experimenting how to vary the amount of quartz and feldspar which he adds to his mixture in order to produce one which, with the new kaolin, will give as good results as the old one.

The method of rationally analyzing clays is discussed under the "Chemical Analysis of Clay" (pp. 29-33), but a few points regarding it

may also be stated here. Clays may agree in their ultimate chemical composition, but disagree widely in their rational composition. Clays showing the same rational composition, will, other things being equal, usually have the same shrinkage. If they differ in the degree of fineness of their particles, they may show a different shrinkage, even though they analyze alike rationally. In porcelain and white earthenware manufacture the clay is generally ground so fine that this last point does not have to be considered.

A rational analysis has been made of the kaolins of North Carolina.

The fact that a kaolin does not contain 98% of clay substance need not cause the slightest uneasiness. The important requirement is a very low percentage of iron. If in addition to clay substance the clay contains quartz and feldspar, then just so much less quartz and feldspar will have to be added in making up the porcelain or other mixture. The celebrated French kaolins which do not have to be washed sometimes contain 38% feldspar.¹

An examination of the following table shows that there is considerable variation in the proportion of clay substance, quartz and feldspar present.

Table showing variation in clay substance, quartz and feldspar.

Percentage of clay substance, quartz, and feldspar in North Carolina kaolins.

Locality.	Clay substance.	Quartz.	Feldspar.
Sylva (washed), N. Ca. Min. & Mfg. Co. (57)	94.21		5.75
Webster (washed), Harris Clay Co. (53)....	96.81	0.07	3.12
" (unwashed), G. Springer (54)	66.14	15.61	18.91
" (washed), G. Springer (56).....	93.24		6.60
Bostick Mills (unwashed) (21).....	49.30	41.50	9.20
" " " (22).....	36.05		62.33
" " (washed) (20).....	54.30	43.85	1.82
Troy, darker kaolin (64a).....	14.71	83.94	1.91
" " " (64) (washed).....	20.83	76.20	2.34
" white kaolin (68) "	58.92	35.27	5.81
West's Mill, Macon Co., crude kaolin (69)...	83.39	14.98	1.58

It will be seen from the above that the free sand or insoluble residue in the North Carolina kaolins is nearly all quartz.

The variations in the total percentages of the washed samples is as follows:

Variation in composition of kaolin, washed samples.

Silica.....	44.08 to 86.03%
Alumina.....	6.46 " 41.70
Ferric oxide.....	.28 " 2.97
Lime.....	.15 " .50
Magnesia.....	.09 " .20
Alkalies.....	.25 " 2.48
Water (loss on ignition).....	2.90 " 13.56

¹ Seger's Ges. Schrift, p. 552.

The special point of interest in these analyses is the iron percentage. The per cent. of iron in the various washed kaolins and their color on burning are as follows:

Table showing per cent. of ferric oxide in washed kaolin, and color on burning.

Locality.	Ferric oxide, percentage.	Color of burned clay.
G. Springer, Webster.....	{ .28 & 1.08 FeO.	White.
West's Mill	1.18	White.
Harris Clay Co., Webster	1.41	White.
Sylva.....	1.86	White.
Bostick Mills.....	2.14	{ White, faint yellow tinge.
Dark kaolin, Troy.....	2.18	Light buff.
White kaolin, Troy.....	2.97	Red buff.

This affords an interesting series from which to determine the permissible limit of iron in a kaolin. It would seem from this that the extreme safety limit is 2%, but still under 1.5% is more desirable. It should be remembered that there might be 2 or 3% of ferric oxide without its presence being noticed, provided there was also present 6 to 9% of lime to bleach it. But still it is undesirable to have to count on this, and even if this condition existed the kaolin would burn yellowish white and not pure white.

MINING OF KAOLIN.

Kaolin is usually soft enough to be mined with a pick and shovel.

If the kaolin deposit is large and broad, it can be worked as an open pit, digging out the material with picks and shovels and loading it into wheelbarrows or cars, which are drawn or pushed to the washing troughs, or, if the pit is deep, brought to the foot of an incline and then hauled up by means of a cable.

Most of the North Carolina kaolin deposits are vein formations whose depth is comparatively great as related to their width. In such instances the method of sinking pits is adopted. This consists in sinking a circular pit in the kaolin about 25 feet in diameter. As the pit proceeds in depth it is lined with a cribwork of wood, as shown in fig. 2 of Plate III, which will be found facing page 56. This lining is extended to the full depth of the pit, which varies from 50 to 100 or even 120 feet. When the bottom of the kaolin has been reached the filling-in of the pit is begun, the cribwork being removed from the bottom upwards as the filling proceeds. If there is any overburden it is generally a good plan to use this for filling in the pits.

As soon as one pit is filled a new one may be sunk in the same manner right next to it. In this way the whole vein is worked out, and, if the

deposit is large, several pits may be sunk at the same time to increase the output of the mine.

The kaolin is taken from the pit in buckets, which are operated by a derrick. At the mouth of the pit it is discharged into barrows or cars.

Two other methods of mining may be mentioned.

If the deposit is deep and narrow, and the better portions of the kaolin are irregularly scattered through the vein, it may be cheaper to sink a shaft and run levels from this into the better parts of the bed. These levels generally have to be timbered and the shaft also requires lining.

Hydraulic mining has been tried with success in some very sandy, loose-grained kaolins, but is not used in North Carolina. The method as sometimes used consists in washing the clay down into the bottom of the pit, whence it is sucked up by means of a pump and discharged from the conveying pipe into the washing trough.

It is sometimes necessary to have a scraper to stir or loosen up the clay in order to permit its being sucked up more easily. Where applicable, this is a cheap and rapid method, but most kaolins are too dense and not sandy enough to permit its being used.

At the Harris Clay Company's mines, near Webster, the mines are at a higher level than the washing plant, and the kaolin, after being trammed for a few hundred feet from the mouth of the pits, is discharged directly into a trough leading down the slope to the washing works. A current of water is pumped up the slope and discharged into the trough to wash the kaolin down.

A kaolin bed to be of commercial value should not be less than 8 feet thick.

The workable depth depends on the distance below the surface to which the feldspar has kaolinized.

PREPARATION OF KAOLIN FOR MARKET.

Most kaolins are washed before shipment. This is done to eliminate coarse particles and substances such as iron, which would render the clay fusible or discolor it in burning.

Two methods of washing may be used. The first consists in throwing the kaolin into large circular tubs or "blungers" filled with water; in these tubs there revolve arms which stir the mass up to a mixture of creamy consistency. By this treatment the fine kaolinite particles and some very fine quartz, feldspar and mica grains remain in suspension while the coarser particles drop to the bottom. The water, with the kaolin in suspension, is then drawn off to the settling tanks.

A modification of this consists in the use of a large cylinder, closed at both ends. The cylinder is set in a horizontal position and contains an axis with iron arms, which as the axis revolves serve to break up the

clay. The latter is charged through a hopper, and a current of water passes into the end of the cylinder, while at the other end the water passes out with the fine clay particles in suspension, the coarser ones remaining in the cylinder.

The amount of water used has to be regulated by experiment. If an excess is used, too much coarse material will be washed out of the cylinder, and conversely if the current is too slow, the clay will not yield a sufficient percentage of washed material. The coarse sand remains in the cylinder and has to be removed from time to time, depending on the capacity of the cylinder and amount of coarse sand in the clay. When the water and suspended clay leave the machine they are conducted to the settling tanks.

This method is little used in this country for the purification of the crude material, although it is extensively used abroad.

The prevalent method of washing kaolin in the United States is by means of troughs, and the details of this method are as follows:

As the kaolin comes from the mine it is generally discharged into a log-washer. This consists of a semi-cylindrical trough, in which there revolves a horizontal axis bearing short arms. The action of these arms breaks up the kaolin more or less thoroughly, depending on its density, and facilitates the subsequent washing. The stream of water directed into the log-washer sweeps the kaolin and most of the sand into the washing troughs, which latter are about 15 inches wide and 12 inches deep. They may be wider and deeper if the kaolin is very sandy; in fact, they should be. The troughing is about 700 feet long, and to utilize the space thoroughly it is broken up into sections (50 feet each is a good length), these being arranged parallel, and connecting at the ends, so that the water, with suspended clay, follows a zig-zag course. This trough has a slight pitch in the North Carolina plants, being about one inch in 20 feet, but this is a matter depending on the kaolin. If the kaolin is very fine and settles slowly, the pitch need not be so great, and vice versa. A large quantity of very coarse sand in the kaolin is a nuisance, as it clogs up the log-washer and upper end of the trough more quickly, and causes so much more labor to keep them clear. As it is, considerable sand settles there, and, to keep the trough clear, sand wheels are used. These are wooden wheels bearing a number of iron scoops on their periphery. As the wheel revolves these scoops catch up a portion of the sand which has settled in the trough, and as each scoop reaches the upper limit of its turn on the wheel, it, by its inverted position, drops the sand outside of the trough. These sand wheels are a help, but it is very often necessary to keep a man in addition shoveling the sand from the trough.

A general view of the kaolin-washing plant at the Harris kaolin mine

near Webster is shown in Plate III, fig. 1. At the end of the shed on the right are the four sand wheels. Next to these comes the troughing, while in the lowest part of the illustration in front of the house are the settling tanks. In the background along the foot of the hill are the drying racks.

If the sand is finer it is not dropped so quickly, but distributed more evenly along the trough and does not clog it up so fast.

The zig-zag arrangement of the troughing has been objected to by some, as it produces irregularities in the current, causing the sand to bank up in the corners at the bends, and also at certain points along the sides of the troughing.¹

The effect of this is to narrow the channel, and consequently increase the velocity of the current, thereby causing the fine sand to be carried still further towards the settling tanks.

This difficulty, which is not often a serious one, has been obviated either by having the troughing straight, or by allowing the water and suspended clay as it comes from the logwasher to pass through a section of straight trough, and from this into another one of the same depth but five or six times the width and divided by several longitudinal partitions. The water and clay then pass into a third section, twice as wide as the second, and divided by twice the number of longitudinal divisions.

By this means the water moves always in a straight course, but as it is being continually spread out over a wider space it flows with an ever decreasing velocity.

By the time the water has reached the end of the troughing nearly all of the coarse grains have been dropped and the water is ready to be led into the settling vats, but as a further and necessary precaution the water is discharged onto a screen of 100 meshes to the linear inch. The object of this is to remove any coarse particles that might possibly remain, and also to remove sticks and other bits of floating dirt that are sure to be introduced.

Two kinds of screens can be used: 1, stationary, and 2, revolving.

The stationary screen is simply a frame covered with 100-mesh copper cloth and set at a slight angle. The water and suspended kaolin fall on this and pass through. If they do not they run off the screen and are lost.

A slight improvement is to have two or three screens overlapping, so that whatever does get through the first will fall on the second.

If the vegetable matter and sticks are allowed to accumulate they clog the screen up and nothing will run through. These stationary screens therefore have to be closely watched.

The revolving screens are far better, for they keep themselves clean.

¹ E. Hotop. *Thonindustrie Zeitung*, 1893.



FIG. 1.—KAOLIN WASHING AND DRYING PLANT, HARRIS CLAY CO., NEAR WEBSTER.
(See also page 61.)

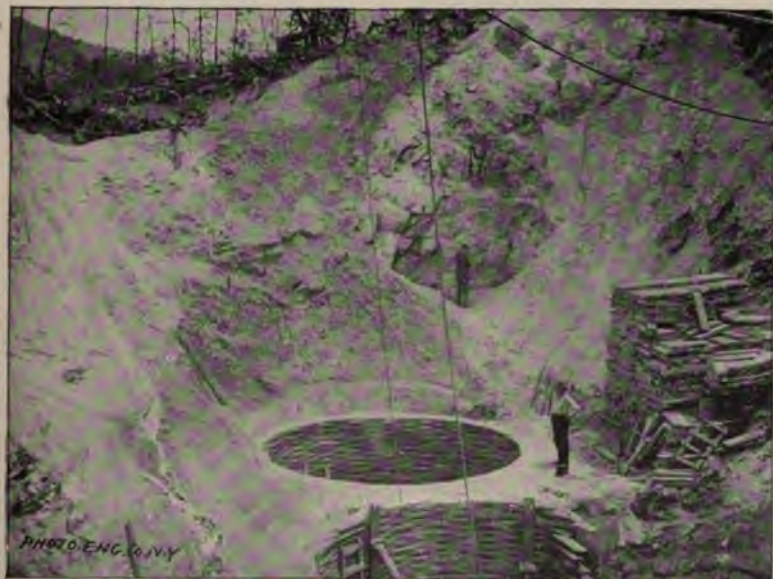


FIG. 2.—KAOLIN MINE, HARRIS CLAY CO., NEAR WEBSTER.
Showing method of sinking pits in the soft kaolin. (See pages 53 and 60.)



Such a screen is barrel-shaped, and the water, with the kaolin in suspension, is discharged into the interior and passes outward through the screening. As the screen revolves, the dirt caught is carried upwards and finally drops; but instead of dropping down upon the other side of the screen, it falls upon a board which diverts it out on to the ground.

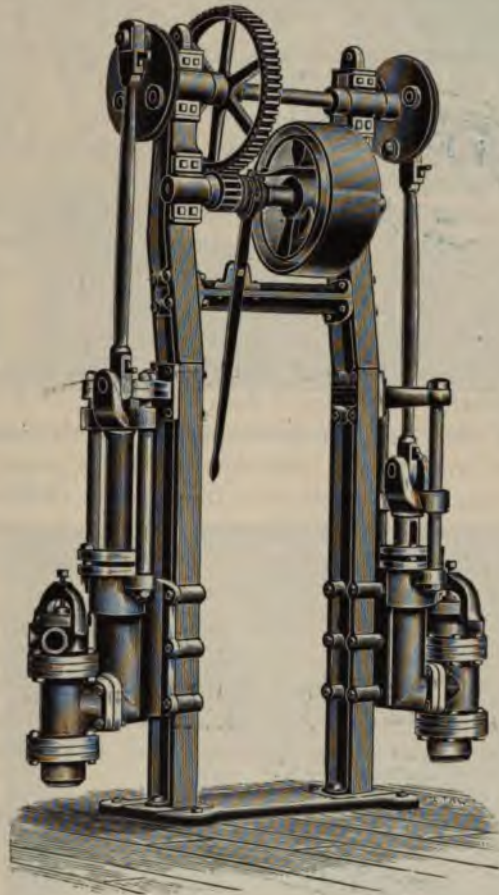


FIG. 1.—PUMP USED IN FORCING KAOLIN SUSPENDED IN WATER FROM THE
SETTLING VATS INTO THE PRESSES.

The settling tanks into which the kaolin and water are discharged may be, and often are, about 8 feet wide by 4 feet deep and 50 feet or more long. As soon as one is filled the water is diverted into another.

The larger a settling tank, the longer it will take to fill it and allow the kaolin to settle, and delays due to this cause are expensive, especially when the market takes the output of washed kaolin as soon as it is ready. Too many small tanks increase the initial cost of plant.

If the kaolin settles too slowly, alum is sometimes added to the water to hasten the deposition. When the kaolin has settled most of the clear water is drawn off, and the cream-like mass of kaolin and water in the bottom of the vat is drawn off into the slip pumps and forced by them into the presses. Figure 1, on the preceding page, shows a form of pump used for this purpose, made by the Turner, Vaughn and Taylor Company of Cuyahoga Falls, Ohio.

The presses consist simply of a series of flat iron or wooden frames between which are flat canvas bags. These bags are connected by nipples with the supply tube from the slip pumps. By means of the pressure from the pumps nearly all of the water is forced out of the kaolin and through the canvas.

When all the water possible is squeezed out the pressure is removed, the press opened, and the sheets of semi-dry kaolin taken out. These sheets are rolled up and put on the racks out in the open air or in a steam-heated room to dry.

Plate IV, fig. 1, shows a kaolin filter press with wooden frame, and fig. 2, such a press with an iron frame. The latter is preferable, especially in climates where wood decays easily.

In a plant of steady and moderate capacity, both economy and ease may be practised by paying a little attention to its proper arrangement.

It is a good idea to have cars on a track, or an endless belt run past the presses and drying racks. The clay can then be taken right from the presses and put on the cars or belt and taken right from them and put on the racks.

As for every ton of crude kaolin usually only about two-fifths or sometimes one-quarter of a ton of washed kaolin is obtained, the importance of having the washing plant at the mines will be easily seen, for it avoids the hauling of 60 to 70% of useless sand, which has to be washed out before the kaolin can be used or even placed on the market.

DEPOSITS OF KAOLIN IN NORTH CAROLINA.

KAOLIN IN JACKSON COUNTY.

NEAR SYLVA.—North Carolina Mining and Manufacturing Co. The kaolin mine of this company is two miles south of Sylva on the mountain slope. The wall rock is a gneiss, now largely decomposed to a ferruginous clay. The kaolin vein cuts this, striking about N. 45° E. Its exact width is not known, but it is 8 to 10 feet in places. A 50-foot shaft has been sunk on the vein, and from the foot drifts have been run in both directions along the vein. This drift is about 4 feet wide and 6 feet high. That running to the east from the shaft is about 150 feet long, including two offsets due to faulting of 16 feet each. The



FIG. 1.—WOODEN FRAME FILTER-PRESS FOR REMOVING THE WATER FROM THE WASHED KAOLIN.



FIG. 2.—IRON FRAME FILTER-PRESS, FOR REMOVING THE WATER FROM THE WASHED KAOLIN.







FIG. 1.—RESIDUAL KAOLIN DEPOSIT, HARRIS CLAY CO., WEBSTER.

View looking N. E. along the strike, shows only half of the vein, the rock on the left being a large lens of quartz in the center of the vein.



FIG. 2.—RESIDUAL CLAY DEPOSIT, NEAR GROVER.

Belonging to the Powhatan Clay Manufacturing Company. (See page 82.)

drift running west has gone only a short distance. A second tunnel was started towards the east, about 8 feet above the bottom of the shaft.

There are streaks of so-called "sand" at several points in the mine, which are patches of only partially kaolinized rock. Several tons of fresh feldspar have been shipped from this mine. The washed clay is very fine-grained with no grit. Color pure white. Very smooth. Slakes slowly but very completely. To produce a workable paste 40% of water was required. This paste was lean, and shrunk 8% in drying and 4% in burning, giving a total shrinkage of 12%. The tensile strength of air-dried briquettes made from this paste was 15 lbs. per square inch.

Incipient fusion occurs at 2200° F., vitrification at 2450° F., and viscosity at 2700° F.

The clay burns to a pure white, smooth body.

The shrinkage in drying and burning is 3% less than in the case of the kaolins from Florida.¹

The following is the analysis of this clay:

Analysis of washed kaolin (No. 57) N. C. Mining & Mfg. Co., two miles south of Sylva.

Moisture	3.07
Silica (total)	44.08
Alumina	36.26
Ferric oxide	1.86
Lime	.43
Magnesia	.20
Alkalies	.50
Water (loss on ignition)	13.56
Total	99.06
Free sand	5.75
Total fluxes	2.99

From this analysis we get:

Clay substance	94.21
Quartz and feldspar	5.75

Specific gravity	2.31
------------------------	------

The insoluble residue was not analyzed separately, as there was such a small amount of it.

From the analysis it will be seen that the clay contains a high percentage of clay substance.

NEAR WEBSTER.—Harris Clay Company. The kaolin deposit of this company is a large and very coarse pegmatite vein or dike with a maximum thickness of nearly 300 feet. In the middle there is a large thick lens of quartz. (Plate V, fig. 1.)

¹ Langenbeck, *Chemistry of Pottery*, 101.

The vein runs almost north and south, and the kaolin is of high quality, but has some quartz and mica, and occasionally garnet mixed in with it.

The wall rock is a reddish, fine-grained, much decomposed gneiss, and the boundary between the kaolin and gneiss is not always sharp. There are really three distinct "veins" of kaolin included in the 300 feet mentioned above. A tunnel was driven across a portion of the deposit from west to east, and the materials which were passed through, together with their thickness, were as follows:

Section across the Harris Kaolin Mine near Webster.

Kaolin	28 ft.
Gneiss	23 "
Quartz	32 "
Kaolin (exposed in V tunnel).....	56 "
Kaolin (bored through)	21 "
Kaolin (exposed in shaft)	22 "
182 ft.	

The 21 feet exposed in boring were through kaolin, and ended in a shaft 22 feet wide sunk in the eastern half of the vein. There were several feet of kaolin beyond this shaft, giving over 100 feet of solid kaolin in the eastern half of the vein. The tunnel was about 70 feet below the surface.

The pits sunk in the kaolin vary from 15-25 feet in width and 80-100 feet in depth. The deepest thus far sunk is 125 feet through solid kaolin. (Plate III, fig. 2, p. 56.)

Since April, 1896, the company has been following the strike of the vein down the hill, toward the north, and has sunk several new pits in this direction.

The washed kaolin from this mine is smooth to the taste and feeling and shows little or no grit. In water it falls slowly but completely to a fine powder. Forty-two per cent. of water were required to give a workable paste, which was somewhat lean. It shrunk 6% in drying and 4% in burning, giving a total shrinkage of 10%. The average tensile strength of air-dried briquettes was 20 lbs. per square inch with a maximum of 22 lbs. Incipient fusion occurred at 2300° F., vitrification at 2500° F., and viscosity above 2700° F.

The clay burns to a white body. The ultimate and rational analysis of this kaolin yielded the following results:

Analysis of Kaolin (No. 53), Harris Clay Co.'s Mine, Webster.

	Washed kaolin.	Portion insoluble.
Moisture	.35	....
Silica	45.70	2.00
Alumina	40.61	0.55
Ferric oxide	1.39	0.27
Lime	0.45	....
Magnesia	0.00	....
Alkalies	2.82	0.37
Water (loss on ignition)	8.98	....
Total	100.39	3.19
Free sand	3.19	....
Total fluxes	4.75	....
Specific gravity	2.43	....

This gives the following:

Clay substance	96.81
Quartz	0.07
Feldspar	3.12
	100.00

The kaolin as mined is discharged into the upper end of a trough, along which it is washed down to the works. It is discharged into the upper end of the washing troughs, and, with the water, passes along under 5 sand wheels, which extract a large amount of the fine sand and keep the trough from becoming clogged. The kaolin, sand and water then pass along 700 feet of troughing, gradually dropping the sand, until the settling tanks are reached. There are 3 troughs, 4 pumps and 4 presses, open-air drying racks, and a steam-drying room. The capacity of the works is 24 tons per day of washed and dried kaolin. (See Plate III, p. 56.)

The washed kaolin has to be hauled four miles to the railroad at Dillsboro. The clay is dried in the steam chamber in three days, while on the racks it requires two weeks.

SPRINGER CLAY PIT.—Geo. Springer, Jr., has recently opened a mine of kaolin on the property of Wm. Buchanan, one-half mile northeast of Webster. A drift has been run in from the side of the hill and across the vein. In this tunnel the vein of kaolin shows up 25 feet wide and strikes N. 15° W.

Two headings have been run north and south from the drift for a distance of five feet. About 50 tons of the crude material have been thus far taken out.

The kaolin appears to be of excellent quality, but the presence of some coarse angular quartz fragments necessitates its washing.

Both the crude and washed clays were tested, and the two series of tests are given in parallel columns for the sake of comparison. No. 54 is the crude material and No. 56 the washed kaolin.

Physical tests of Kaolin, washed and crude, Springer pit.

	No. 54. Crude kaolin.	No. 56. Washed kaolin.
Character	Coarse to fine. Sandy.	Very fine. Smooth.
Slaking	Fast and complete.	Slow and complete.
Water required to give paste.....	32%	38%
Plasticity	Lean.	Lean.
Air shrinkage	2	8
Fire shrinkage	4	4.5
Average tensile strength	6 lbs.	23
Maximum tensile strength	7 lbs.	24
Condition when burned	Porous.	Dense.
Color when burned	White.	White.
Incipient fusion	2300° F.	2350° F.
Vitrification (incomplete)	2500° F.	2550° F.
Viscosity	above 2700° F.	above 2700° F.

Analysis of Kaolin, Springer pit, ½ mile N. E. of Webster.

	No. 54.* Crude kaolin.	Insoluble residue.	No. 56. Washed kaolin.	Insoluble residue.
Moisture	.25	.....	2.05	.....
Silica	62.40	29.12	45.78	6.60
Alumina	26.51	3.85	36.46	.....
Ferric oxide	1.14	.65	.28	.....
Ferrous oxide .....	.....	.....	1.08	.....
Lime	.57	.....	.50	.....
Magnesia	.01	.....	.04	.....
Alkalies	.98	.90	.25	.....
Water (loss on ignition) ..	8.80	.....	13.40	.....
Total	100.66	34.52	99.84	-----
Fluxes	2.70	.....	2.15	.....
Specific gravity	2.58	.....	2.27	.....

From the rational analysis we get the following:

Clay substance	66.14	93.24
Quartz	15.61	6.60
Feldspar	18.91	

It is plain that the effect of the washing has been to eliminate the percentage of quartz and feldspar and relatively increase the clay substance nearly 30%. Of the fluxes only the alkalies have been decreased.

KAOLIN IN MACON COUNTY.

NEAR WESTS MILL.—On the land of Geo. Brindel, near Wests Mill, is a deposit of kaolin of remarkable whiteness, which burns to a

* Composition of Clay substance of 54:

Silica.....	50.50	Alumina.....	34.24	Ferric oxide....	0.74
Lime.....	0.86	Magnesia.....	0.01	Alkalies	0.10
		Water	13.35		

pure white color, showing its excellent quality. It is very fine-grained, free from grit, and shows a few scattered white mica scales. It slakes slowly but thoroughly.

The addition of 31% of water gave a workable paste of the usual lean character. The bricks made from this paste shrunk 6% in drying and 6% in burning, giving a total shrinkage of 12%. The air-dried briquettes had an average tensile strength of 15 lbs. per square inch and a maximum of 18 lbs. Incipient fusion occurs at 2300° F., vitrification at 2600° F., and viscosity at over 2700° F. The clay burns to a pure white body.

The following analysis of the unwashed sample shows its remarkable purity:

Analysis of Kaolin (No. 69) from Geo. Brindel's land, near Wests Mill.

	Crude kaolin.	Insoluble residue.
Silica (total)	53.10	15.23
Alumina	33.06	0.07
Ferric oxide	1.18	0.46
Lime	0.38	....
Magnesia	0.08	....
Alkalies	0.83	0.80
Water (loss on ignition).....	11.32	....
Total	90.95	16.56
Total fluxes	2.47	
Specific gravity	2.31	

From the above we get:

Clay substance	83.39
Quartz	14.98
Feldspar	1.58

Subtracting the second column from the first, we get the composition of the clay substance, which, in the second of the two following columns, is recalculated to 100. The clay substance, it will be seen, is nearly pure kaolinite, but with a slightly greater amount of alumina in proportion to the silica than is called for by the formula of kaolinite:

Composition of Clay Substance in Kaolin from Wests Mill.

Silica	37.87	45.41
Alumina	32.90	39.56
Ferric oxide	0.72	0.86
Lime	0.38	0.45
Magnesia	0.08	0.09
Alkalies	0.03	0.03
Water (loss on ignition).....	11.32	13.58
	83.39	99.98

KAOLIN IN MONTGOMERY COUNTY.

NEAR TROY.—Considerable quantities of kaolin have recently been discovered 4 miles west of Troy, Montgomery county.

From the various outcrops two samples were tested.

The first sample forwarded (No. 64) was a darker kaolin. This was a fine-grained, gritty clay, which passes almost entirely through a 60-mesh sieve. It slakes easily and quickly to fine grains.

The sample when washed yielded a residue of 40%, which is probably somewhat larger than would be obtained in actual practice, and this washed kaolin required 30% of water to produce a workable paste that was lean to the feeling. This paste shrunk 3% in drying and an additional 10% in burning, giving a total shrinkage of 13%. The average tensile strength of air-dried briquettes was 9 lbs. per square inch with a maximum of 12 lbs. per square inch. Incipient fusion occurred at 2100° F., vitrification at 2300° F., and viscosity at 2500° F.

The clay burns to a very pale buff.

The second sample forwarded was a white kaolin (No. 68) and does not possess the grayish tint which the other does. It shrank 3% in drying and 9% in burning, giving a total shrinkage of 12%. The air-dried briquettes had an average tensile strength of 10 lbs. per square inch with a maximum of 12 lbs. Incipient fusion occurs at 2100° F., vitrification at 2300° F., and viscosity at 2500° F. The kaolin burns to a deeper buff than the preceding one.

The coloration of these two kaolins is against their use for white-ware, but they might be used for higher grades of stoneware, encaustic tiles, or in the body of refractory wares for laboratory use.

The crude white kaolin was at first tested, as its snow-white color suggested that it might burn white and to a dense body without further treatment. The results obtained were so similar to those of the washed white kaolin that they are simply given in the appended table. The tensile strength of the crude material was a few pounds greater and the shrinkage in burning three per cent. less.

An examination of the following analyses indicates the rather high iron percentage which accounts for the color of the burned clay. A comparison of the analysis of the washed and crude kaolin also points out that the percentage of sand has been reduced, but none of the iron removed.

In the following analyses No. 64a represents the darker kaolin (crude) from 4 miles west of Troy, No. 64 this darker kaolin washed, and No. 68 the white kaolin washed from the same locality.

Analyses of Kaolin 4 miles W. of Troy, Montgomery Co.

	No. 64a.	No. 64.	No. 68.
Moisture	.48	.53	.75
Silica	90.13	86.03	63.10
Alumina	4.99	6.46	23.33
Ferric oxide	1.86	2.14	2.97
Lime	.13	.17	.15
Magnesia	.01	.04	.09
Alkalies	1.03	1.00	1.90
Water (loss on ignition)....	1.93	2.90	7.65
Total	100.56	99.27	99.94
Insol. residue	85.85	78.54	41.08
Total fluxes	3.03	3.35	5.11
Specific gravity	2.47	2.32	2.84

Analyses of insoluble residue from the above.

	No. 64a.	No. 64.	No. 68.
Silica	84.64	77.25	38.25
Alumina	.20	.30	.85
Ferric oxide	.37	.26	.46
Alkalies	.64	.73	1.52
	85.85	78.54	41.08

From the above, by a rational analysis, we get the percentages of the mineral ingredients as follows:

Mineral Composition of Kaolin 4 miles W. of Troy, N. C.

	No. 64a.	No. 64.	No. 68.
Clay substance	14.71	20.83	58.92
Quartz	83.94	76.20	35.27
Feldspar	1.91	2.34	5.81

Composition of the clay substance in the above.

	No. 64a.	No. 64.
Silica	38.58	43.46
Alumina	33.06	30.04
Ferric oxide	10.46	9.30
Lime	.91	.84
Magnesia	.07	.19
Alkalies	2.70	1.33
Water (lost on ignition)	13.56	14.35
	99.94	99.51

KAOLIN IN RICHMOND COUNTY.

NEAR BOSTICK.—Considerable residual kaolin has recently been found on the property of Robert W. Steele, near Bosticks Mills, 14 miles north of Rockingham, Richmond county. A number of test pits have been sunk and the exploitations indicate the presence of an

abundant amount of material. The deposit could be readily transported to market. It is two miles from the end of a lumber railroad, and after hauling to this point the lumber company would transport it to the railroad at Hoffman, a distance of 12 miles, for not exceeding 50 cents a ton; or this timber railroad could be extended easily and cheaply to the kaolin deposit.

The first point at which the kaolin appears is one mile south of Bostick P. O. and near Christopher Bostick's cabin, where it crops out for a distance of fifty feet in a ditch by the roadside. It is next seen on the opposite side of the road, at base of hill, but between these two exposures is a red clay resulting from the decomposition of schistose rock.

Just east of the first-mentioned exposure, and in the woods about 100 feet from the road, a test pit four feet square has been sunk (No. 21). This showed $1\frac{1}{2}$ feet overburden and then 3 feet kaolin. The pit had been sunk 10 feet through kaolin, but had caved in. About 30 feet from this another pit was sunk to a depth of 12 feet. This also shows the kaolin from one foot below the surface down to the bottom (No. 20). Several other small pits have been sunk within a radius of 75 feet, and all penetrated the kaolin. The material is fine-grained, with comparatively few angular fragments. There are scattered stains of iron, but these may disappear with depth.

Another series of pits (No. 22) have been sunk on Mr. Chapel's land, one mile due west of No. 21. These pits were sunk to a depth of 10 feet, and the kaolin appeared at 18 inches from the surface and continued to bottom of pits. This kaolin is whiter than that at 21. Between the two deposits there is a shallow valley, and it is not known whether 21 and 22 are portions of one vein or not.

Samples of Nos. 20, 21 and 22 were tested in their crude condition, and Nos. 20 and 22 were also washed.

No. 20 is a fine-grained kaolin with little coarse grit, which slakes slowly but completely to a fine-grained mass. It required 27.7% of water to give a workable paste, which shrank 4% in drying and 9% in burning. Incipient fusion occurs at 2250° F., vitrification at 2500° F., and viscosity at 2700° F. The average tensile strength of air-dried briquettes was 10 lbs. per square inch with a maximum of 14 lbs. per square inch. The clay burned to a dense body with slightly yellowish tint.

No. 21 slaked the same as 20. It required 26% of water to make a workable but lean paste, which shrank 3.5% in drying and 8% in burning. Incipient fusion occurred at 2300° F., vitrification at 2500° F., and viscosity at 2700° F. The clay burns to same tint as No. 20. Its average tensile strength was 13 lbs. per square inch, with a maximum of 16 lbs. per square inch.

No. 22 is a somewhat porous, fine-grained white clay with comparatively little grit, which slakes slowly but completely to fine grains.

It required 27.7% of water to make a workable but lean paste. This paste shrunk 4% in drying and an additional 8% in burning. The average tensile strength of the air-dried briquettes was 15 lbs. per square inch with a maximum of 16 lbs.

Incipient fusion occurs at 2250° F., vitrification at 2450° F., and viscosity at over 2700° F.

The following analyses of these three samples (crude kaolin) were made:

Analyses of Kaolin near Bosticks Mills, 14 miles N. of Rockingham, Richmond Co.

	No. 21.		No. 20.*		No. 22.	
	Crude Kaolin.	Insol. in H ₂ SO ₄ etc.	Crude Kaolin.	Insol. in H ₂ SO ₄ etc.	Crude Kaolin.	Insol. in H ₂ SO ₄ etc.
Silica	68.15	47.45	70.63	48.10	73.70	62.33
Alumina	19.99	1.70	21.81	3.24	16.03	....
Ferric oxide	1.86	.20	1.49	.56	1.57	....
Lime	.13	....	.20	....	.38	....
Magnesia	.16	....	.29	....	.47	....
Alkalies	2.85	1.35	1.45	} Na ₂ O .72 K ₂ O .24 }	1.90	....
Moisture	.17	....	.08		....	....
Water (loss on ignition). 4.70	....	....	4.04	....	4.33	....
Total	98.01	50.70	99.99	52.86	98.38	62.33
Total fluxes	5.00	....	3.43	....	4.32	....
Specific gravity	2.52	....	2.41	....	2.43	....

From the above we obtain the mineralogical composition of the kaolins as being:

Mineral composition of Kaolin near Bosticks Mills.

	No. 21.	No. 20.	No. 22.
Clay substance	49.30	47.14	36.05
Feldspar	9.20	16.13	} 62.33
Quartz	41.50	36.73	

A 5-lb. sample of No. 20 was washed. The settlings amounted to 40%, which is probably somewhat larger than would be obtained in actual practice. The washed kaolin required 26% of water to give a workable paste that was lean but smooth. This paste shrunk 3% in

* Composition of Clay Substance of No. 20:

Silica.	47.88
Alumina.	39.04
Ferric oxide	1.90
Lime	0.42
Magnesia.....	0.60
Alkalies.....	1.04
Water	8.58
	99.46

drying, and there was an additional shrinkage of 9% in burning. Incipient fusion occurred at 2250° F., vitrification at 2450° F., and viscosity at over 2700° F. There was a faint yellowish tint to the burned ware.

Sample No. 22 was also washed. The washed material was 35% of the original mass. It required 29% to give a lean but workable paste that shrunk 4% in drying and 7% in burning, giving a total shrinkage of 11%. The air-dried briquettes had an average tensile strength of 8 lbs. per square inch and a maximum of 11 lbs. Incipient fusion occurs at 2250° F., vitrification at 2450° F., and viscosity at over 2700° F. The clay when washed was pure white, but when burned had the faintest yellow tint.

An analysis was made of the washings from No. 20 and yielded the following percentages:

Analysis of Washings from Kaolin (No. 20), near Bosticks Mills.

	Total portion.	Insoluble portion.
Silica	71.12	44.38
Alumina	19.61	.15
Ferric oxide	2.18	.37
Lime	.17	.....
Magnesia	.08	.....
Alkalies	2.48	.77
Water (loss on ignition).....	4.33	.....
Total	99.97	45.67

From the above we get the following:

Mineral composition of washings from the Bostick Kaolin No. 20.

Clay substance	54.30
Quartz	43.85
Feldspar	1.82

Composition of clay substance from the Bostick Kaolin, sample No. 20.

Silica	49.33
Alumina	35.90
Ferric oxide	3.15
Lime	.31
Magnesia	.14
Alkalies	3.15
Water (loss on ignition)	8.00
Total	99.98

USES OF THE NORTH CAROLINA KAOLINS.

The foregoing tests of the kaolins from several localities are to be looked upon as very promising, for they indicate the presence of much material of a high grade.

It would be possible to make comparisons of the North Carolina kaolins with those from other localities, but such comparisons have little practical value, unless the chemical and physical characters of each clay are known. Many ultimate and rational analyses of foreign kaolins have been published, but few physical tests are given.¹

As a matter of interest, some of the North Carolina kaolins may be compared with celebrated foreign ones which are used in the manufacture of the highest grades of porcelain.

In the following columns the analyses, No. *a* (53) and No. *b*, are those of washed kaolin from the mine of the Harris Clay Co., the first analyzed by Chas. Baskerville, the second by C. Langenbeck.² Number *c* is an analysis of the well-known kaolin from Zettlitz, near Carlsbad, in Bohemia.

Analyses of Kaolins: Webster, N. C. (a and b) and Zettlitz (c).

	No. a (53).	No. b.	No. c.
Silica	45.70	45.80	46.82
Alumina	40.61	39.20	38.49
Water loss on ignition)	8.98	13.11	12.86
Ferric oxide	1.39	.40	1.09
Lime	.45	.45	....
Magnesia	.00	.15	tr.
Alkalies	2.82	.92	1.40
	100.04	100.03	100.00

The washed white kaolin from 4 miles west of Troy, N. C. (No. 68), is interesting to compare with a German kaolin from Sennowitz, near Halle, (*d*) and which is used at Berlin for the manufacture of porcelain.³ The two are very similar in their ultimate composition, but disagree strongly when their rational analyses are compared.

Analyses of Kaolin from Troy, N. C. (68) and Sennowitz, Germany (d).

	No. 68.	No. d.
Moisture	.75	....
Silica	63.16	64.87
Alumina	23.23	23.83
Water loss on ignition)	7.95	8.28
Ferric oxide	2.97	.83
Lime	.15	....
Magnesia	.00	.50
Alkalies	1.90	1.39
	99.94	99.78
Clay component	58.92	63.77
Quartz	35.27	35.50
Flint	5.81	.73

¹Transactions of the American Ceramic Society. ²Chem. Anal. of Pottery. ³Eng. Cer. Soc. p. 2.

The North Carolina kaolins, which contain under one per cent. of ferric oxide, are perfectly well adapted to the manufacture not only of white earthenware, but also of the best grades of porcelain. Those with $1\frac{1}{2}$ to 2% of ferric oxide could no doubt be used for lower grades of white earthenware, while those containing 2 to $2\frac{1}{2}$ % of ferric oxide might be utilized for mixing with fire-clays in the manufacture of refractory apparatus.

Kaolin containing very little grit, which would be the case when it had a very large percentage of clay substance, is eagerly sought after by paper manufacturers. Kaolin is also used in the manufacture of ultramarine. For this purpose it should be as low in iron and lime as possible. An excess of silica is undesirable, but if too little is present it may be added in the form of finely powdered quartz.

CHAPTER VI.

POTTERY CLAYS IN NORTH CAROLINA.

THE POTTERY INDUSTRY.

The pottery industry of North Carolina has thus far been confined entirely to small potteries of perhaps 25,000 gallons annual capacity, whose trade is mostly local. There are between forty and fifty of these small potteries in the state, and most of them are located near Jugtown and Blackburn in Catawba county, and Henry in Lincoln county. There are others scattered over the state, as at Wilkesboro, Wilkes county, two miles north of Morganton, Burke county, and several other localities.

All of the potteries in Lincoln and Catawba counties obtain a large amount of their clay from the lowlands along the Clarke river (south fork of Catawba) two miles north of Lincolnton, some of them having to haul it 14 miles. They pay 50 cents a ton for it, and generally haul the clay on their return from a peddling trip, when their wagons would otherwise be empty.

The clays used for pottery purposes in North Carolina are the finer aluminous sediments underlying the river terraces to be found in many of the broader valleys, and the better ones are generally found near the shore line of the terrace. These terrace deposits of fine-grained, plastic clay are common, and with an increasing demand for pottery clays in the state, an abundance of the necessary material will probably be found close at hand.

In addition to the clay deposits underlying the terraces along Clarke river, especially north of Lincolnton, which have already been mentioned, the Catawba river, which flows by Morganton and Catawba, and thence southward past Mt. Holly, has also a marked terrace development; and the clays north of Morganton have already been used for pottery manufacture.

A third series of deposits of terrace clays is to be found along the Yadkin river.

Those at Wilkesboro emphasize the importance of making a rather thorough search for the proper kind of clay, for the material found there at one point is only suitable for brick, while one-quarter of a mile further it is eminently plastic, smooth, and burns to a dense hard body, just such as is needed for stoneware.

REQUISITES OF A POTTERY CLAY.

This term is meant to include the lower grades of earthenware and stoneware clay. For common earthenware, such as flower-pots, almost any red-burning, plastic clay will suffice, if it permits turning on the potter's wheel and burns to a good red but not vitrified body.

It is also possible to make a very serviceable grade of earthenware from calcareous clays, with up to 20 or 30 per cent. of calcium carbonate (provided it is finely divided and evenly distributed through the clay), and cover the ware with an easily fusible glaze of clay, clay and lead, or a mixture of fusible compounds. The majolica wares made in Italy and Germany are made from such clays.

Stoneware clays require a little more attention.

They should possess good plasticity in order to permit molding or turning without cracking.

Their tensile strength should be preferably not less than 125 lbs. or 150 lbs. per square inch.

They should not shrink excessively in burning, and should burn to a dense vitrified body at a temperature of 2000° F. or 2100° F. if possible. The lower temperature of vitrification is of course an important item of economy. For the same reasons the clay should permit of rapid drying. It should also be smooth and as free from grit as possible.

The fluxing impurities in a stoneware clay should be sufficiently high to produce a vitrified body. Iron is a desirable coloring ingredient. Lime, if in small amounts, 2-3%, is not very objectionable, but a large percentage may bleach the iron color, decrease the shrinkage and increase the fusibility. Calcium sulphate is undesirable, for its dissociation at high temperatures may cause blistering.

It is frequently found that better results can be obtained by mixing two different clays, the one furnishing stiffness and low shrinkage, the other plasticity and easier fusibility. This is done by all of the North Carolina potters, the two clays which they use being mixed in equal proportions, although in their case the chief difference of the clays used is in plasticity and stiffness.

Clays for making yellow ware are generally low grade fire-clays which burn to a buff color. They are usually washed to eliminate any coarse sand and pyrite nodules which they may contain. This is generally done in a circular vat or "blunger," in which there revolve stirrers, as mentioned under "The Preparation of Kaolin" (page 54).

Yellow ware is first molded and burned to incipient fusion, the transparent or opaque glaze applied and the ware burned again.

Some of the shale clays associated with the coal seams in North Carolina might answer for this purpose, but they have not yet been tested.

STONEWARE MANUFACTURE.

The methods at present employed within the State are somewhat crude, but best adapted, perhaps, to the size of the plant and available capital.

The clay is mixed in a vertical box, in which there is set a shaft with iron cross-pieces. This shaft is turned by horse-power, and the clay becomes mixed by the action of the iron arms. Before molding, the clay is further wedged. It is tempered to quite a soft paste, whose total shrinkage in drying and burning is 20-25%, according to the potters. The molding is done on the old-fashioned "kick-wheel," and the green ware dried on shelves set over a long, low, hot-air flue in the centre of the room.

The wares are burned in a long, low kiln resembling a muffle in form. The glaze is either old glass or furnace slag ground fine and applied in the form of a slip. The glass is put on the wares set in the upper end of the kiln, as it melts easier, while the ware set in the lower end of the kiln is coated with the ground slag.

If a pottery clay possesses all the requisite chemical and physical characters but is gritty, it is often possible to remove the grit by washing. This is best done in a circular tub in which there revolve stirring arms, as mentioned under the head of kaolin washing. The water, with suspended clay, is drawn off and the latter allowed to settle in tanks. The clear water is then drawn off and the clay can be dried by steam or in the sun. Sandy clays will dry quicker, but they do not burn to as dense a body.

None of the North Carolina potters use Albany slip for glazing their ware. If they did the product would be far more sightly than it is now. The crude glaze which they use is cheap, but it cracks very soon. With a little experimenting of the proper nature it would be possible to find glazes adaptable to the clays now being used. This, together with the application of improved methods and some care, would enable the North Carolina potter to put a far better grade of ware on the market, and sell it at a correspondingly increased price. At present nearly all of the earthenware and stoneware used in the larger towns and cities of North Carolina comes from other states.

The molding is all done by hand, and in the present state of the industry plaster molds have not been deemed necessary.

As has been already stated, many of these river clays are well adapted to stoneware manufacture, and would give a far better product than is now being made. Their temperature of vitrification is also high enough to bear the application of Albany slip as a glazing material.

The Albany slip is an impure fusible clay found in the Hudson river valley in New York state. It vitrifies at 1800° F. and forms a brown,

evenly colored coat. No other clay has yet been found which has these qualities of such constancy.

In larger stoneware factories the kick-wheel is found insufficient. For the ordinary symmetrical shapes a common potter's wheel can be used, operated by steam power. Crocks, jugs and similar articles are molded on this, the potter throwing a lump of clay on the revolving wheel and then deftly working it up into the desired form simply by using his fingers.

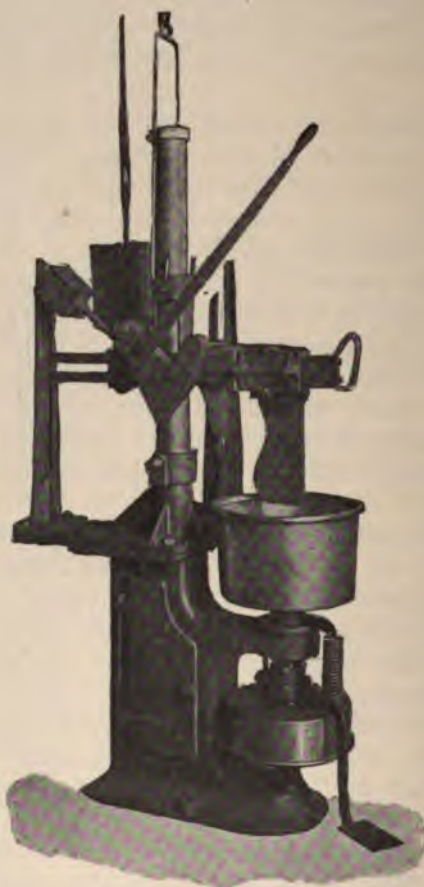


FIG. 2.—THE POTTERS' JOLLY WHEEL, NO. 3.

Many articles are molded on a jolly wheel. With this a plaster of Paris mold is used to form the article. The mold is set on the wheel and, while being revolved, a lump of the tempered clay is thrown into it and worked out in a thin layer over the interior surface of the mold.

The mold is then set aside to dry, and the clay shrinks from the mold and hardens sufficiently to be lifted out. Fig. 2 shows a jolly made by the Turner, Vaughn & Taylor Co., of Cuyahoga Falls, Ohio.

The speed of drying depends on the clay. If possible, the drying is done in a steam-heated room for a number of hours until the ware is dry enough to be burned. If slip glaze is used the ware has to be first dipped into it and once more dried before burning, but if salt glaze is used the ware is put directly in the kiln.

The quicker the drying and burning which a clay will permit without cracking the more economical it is to use it.

Very plastic clays have to be dried slowly to prevent cracking, but this difficulty may be overcome by the admixture of more sandy ones.

Burning may be done in circular kilns, which are either up-draft or down-draft in their action. The burning and cooling take from 5-8 days, depending on the clay.

The water-smoking can generally be carried on rapidly, but the cooling should not be hurried, to avoid cracking.

POTTERY INDUSTRY IN BURKE COUNTY.

NEAR MORGANTON.—Three miles north of Morganton is the North Carolina pottery, at present inoperative, but the plant is one of the largest in the State. The clay which it is claimed was alone used is on Manly McDowell's property, $1\frac{1}{2}$ miles west of Morganton and along the road, an eighth of a mile from the Catawba river.

This clay (No. 51) directly underlies the terrace surface and is a fine-grained, gritty, soft clay, overlain by 18 inches to 2 feet of yellow loam. The bed of clay is 6-7 feet thick.

The addition of 36% of water gave a stiff, somewhat smooth, but rather lean mass, which shrunk 9.6% in drying and 4.5% in burning, giving a total shrinkage of 14.1%.

The air-dried briquettes of this clay had an average tensile strength of 60 lbs. per square inch with a maximum of 81 lbs.

Incipient fusion occurs at 1950° F., vitrification at 2100° F., and viscosity at 2250° F. The clay burns red.

The analysis of the clay is as follows:

Analysis of Pottery Clay (No. 51), Manly McDowell's, near Morganton.

Moisture	1.68
Silica (total)	69.58
Alumina	14.03
Ferric oxide	6.41
Lime	.40
Magnesia	.27
Alkalies	1.65

Water (loss on ignition)	5.73
Total	99.75
Clay substance	45.47
Free sand	54.28
Total fluxes	8.73
Specific gravity	2.59

It is manifestly impossible that pottery could have been made from this clay alone, on account of its low binding power, and a more plastic material must have been mixed with it.

POTTERY INDUSTRY IN CATAWBA COUNTY.

NEAR BLACKBURN.—Many of the potters, especially those at Blackburn, use a highly plastic, dark-colored clay obtained two miles north-west of Blackburn on the property of M. Finger. This clay is smooth, dense, and slakes slowly to irregular, scaly flakes. There is a noticeable amount of organic matter present in it.

The addition of 30% of water was required to give a workable mud, which was very plastic. This paste shrunk 12% in drying and an additional 7% in burning, giving a total shrinkage of 19%. The briquettes made from this clay had when air-dried an average tensile strength of 148 lbs. per square inch and a maximum of 200 lbs. Incipient fusion occurred at 1950° F., vitrification at 2100° F., and viscosity at 2250° F.

The clay burns to a grayish brown body of good density.

The analysis of the clay is as follows:

Analysis of Pottery Clay (No. 50), 2 miles N. W. of Blackburn.

Moisture	2.08
Silica (total)	50.17
Alumina	28.77
Ferric oxide	2.88
Lime	.05
Magnesia	.22
Alkalies	1.04
Water (loss on ignition)	14.03
Total	99.24
Clay substance	73.19
Free sand	26.05
Total fluxes	4.19
Specific gravity	2.35

The high percentage of loss on ignition is due to the several per cent. of organic matter in the clay. This also increases the plasticity and adds somewhat to the air shrinkage.

POTTERY INDUSTRY IN LINCOLN COUNTY.

NEAR LINCOLNTON.—The clay along the Clarke river, northwest and north of Lincolnton, supplies nearly fifty potters in Catawba and Lincoln counties.

The material is a fine-grained gray clay with occasional yellow iron stains. Two samples were tested, No. 61 from the pits at end of lane on T. Rhodes' property two miles northwest of Lincolnton, and No. 49 from about one-quarter mile farther up the river.

No. 61 is a fine, gritty clay with scattered mica scales. It slakes slowly. The addition of 35% of water gave a smooth, very plastic mass which shrunk 10% in drying and 7% in burning, giving a total shrinkage of 17%. The air-dried briquettes of this clay had an average tensile strength of 157 lbs. per square inch and a maximum of 186 lbs.

Incipient fusion occurs at 1900° F., vitrification at 2100° F., and viscosity at 2300° F.

The clay burns to a dark red body.

This clay is not as plastic as that obtained northwest of Blackburn, nor is its tensile strength always so great, as will be seen from the tests of the next sample, but it is a good material for common stoneware.

The analysis of the clay is as follows:

Analysis of Pottery Clay (No. 61), T. Rhodes' land, 2 miles N. W. of Lincolnton.

Moisture	2.10
Silica (total)	57.20
Alumina	24.82
Ferric oxide	3.25
Ferrous oxide	1.42
Lime	.73
Magnesia	.13
Alkalies	.93
Water (loss on ignition)	8.25
Total	98.83
Clay substance	62.27
Free sand	36.57
Total fluxes	6.46
Specific gravity	2.51

Sample No. 49 from the pits on T. Rhodes' property is finely gritty clay which slakes slowly but completely. It required the addition of 40% of water to make a workable paste, which was very plastic to the feel. This paste shrunk 9.5% in drying and 5.5% in burning, giving a total shrinkage of 15%. The air-dried briquettes made from this mud had an average tensile strength of 133 lbs. per square inch and a maximum of 158 lbs.

Incipient fusion occurred at 1900° F., vitrification at 2100° F., and viscosity at 2300° F.

The clay burns reddish white at 1900° F. and deep red at 2100° F.

The composition of it is as follows:

Analysis of Pottery Clay (No. 49), Rhodes' land, 2½ miles N. W. of Lincolnton.

Moisture	.69
Silica (total)	57.08
Alumina	26.11
Ferric oxide	4.64
Lime	.20
Magnesia	.16
Alkalies	1.42
Water (loss on ignition)	8.52
Total	98.82
Clay substance	62.76
Free sand	35.96
Total fluxes	6.42
Specific gravity	2.53

POTTERY INDUSTRY IN WILKES COUNTY.

NEAR WILKESBORO.—At the west end of the village of Wilkesboro a small pottery has used the clay outcropping at the fork of the roads, and also drawn upon an additional bed in a field to the north. .

That dug along the road is a light bluish-white clay, tough, and containing small amounts of fine grit. This is used to furnish stiffness to the potter's mixture, while that from the field across the road furnishes a bond in burning.

The stiff clay (No. 34) is fine-grained and contains little mica. It slaked slowly and required the addition of 40% of water to make a workable paste, which was slightly plastic. This shrunk 7.5% in drying and 12% in burning, giving a total shrinkage of 19.5%. The air-dried briquettes had an average tensile strength of 51 lbs. per square inch and a maximum tensile strength of 63 lbs. per square inch.

Incipient fusion occurred at 1900° F., vitrification at 2050° F., and viscosity at 2200° F. The clay burns red and dense. Its composition is as follows:

Analysis of Pottery Clay (No. 34), near Wilkesboro.

Moisture	1.28
Silica (total)	54.38
Alumina	27.27
Ferric oxide	5.48
Lime	.45
Magnesia	.41

Alkalies	.68
Water (loss on ignition).....	9.78
Total	99.73
Clay substance	75.73
Free sand	24.00
Total fluxes	7.02
Specific gravity	2.37

he north of this locality one-half mile and underlying the broad, er terrace along the Yadkin river, is a large deposit of clay on id of Calvin Cowles. A deep trench has been run across the y, exposing the clay throughout its length, and samples were from this point.

a fine-grained, smooth, dark-colored clay, containing very little It slakes slowly to grains and granules. 35% of water were d to give a workable mixture, which was very plastic. This hrunk 10% in drying and 5% in burning, giving a total shrinkage

The air-dried briquettes had an average tensile strength of 169 r square inch, and the maximum tensile strength amounted to s. per square inch. Incipient fusion occurred at 1800° F., vitri- at 2000° F., and viscosity at 2200° F.

clay burns to a hard, dense, brownish-gray impervious body at F., and should make an excellent potter's clay. It required slow and heating to avoid cracking. The composition of it is as

:

sis of Pottery Clay (No. 35), ½ mile north of Wilkesboro, C. Cowles' land.

Molsture	2.20
Silica (total)	54.24
Alumina	24.97
Ferric oxide	4.83
Lime	.57
Magnesia	.70
Alkalies	2.52
Water (loss on ignition).....	9.40
Total	99.43
Clay substance	67.08
Free sand	32.35
Total fluxes	8.62
Specific gravity	2.46

is not unlike the clay at the pottery, but its finer grain, greater age of alkalies, make it burn dense at a lower heat.

CHAPTER VII.

FIRE-CLAYS AND PIPE-CLAYS IN NORTH CAROLINA.

FIRE-CLAYS.

The fire-clay deposits of North Carolina are few in number as thus far known. They are either residual deposits or the wash from them. There are a number of siliceous clays in the State which at a moderate temperature burn to a cream-white or white color, and the bricks made from these clays are used for bakers' ovens and boiler foundations. They are called fire-brick, but are not such in the true sense of the word.

Refractory clays occur at Pomona, Guilford county, and Grover, Cleveland county, and are mined at both places.

While it is desirable that fire-clays should possess good plasticity and low shrinkage, the main point is the refractory character. A good fire-clay should be unaffected by 2500° F., but many good clays will not stand this degree of heat, nor is it required for the uses to which they are to be put. In general, it may be said that the fusible impurities of a fire-clay should not exceed $3\frac{1}{2}$ or 4 per cent. if it is fine-grained, or even less if it is very fine-grained, but if coarse-grained they may reach even 5%. The clay on the railroad near Spout Springs, for example, has only 3.81% of total fluxes, yet on account of its very fine grain it is by no means refractory. If a fire-clay shrinks too much in burning this may be often counteracted by the addition of "grog," viz., sand, ground fire-brick or other substances which would dilute the shrinkage. Fire-clays which are fat and plastic generally burn to a dense body, but crack considerably owing to their high shrinkage. This may be counteracted best by mixing burned clay of the same or some other kind with the fresh material. This burned clay or grog, should be burned as dense as possible before use. Fine-grained or powdered grog permits the brick to shrink more in burning than coarse-grained, and bricks with the latter generally stand changes of temperature better. Next to burned clay, quartz is the most important grog.

If a fire-brick made only of clay and clay-grog still shrinks when placed in the furnace, sharp quartz grains should be added, as they have a tendency to expand on repeated heatings. Fine-grained quartz sand should in no case be added as it tends to act as a flux in burning. The addition of coarse quartz must also be within limits, for if too large it loosens the stone by expansion.

A good fire-brick is sometimes made by mixing a non-plastic refractory clay with a very plastic, dense burning semi-refractory one.

Fire-brick are now mostly molded by hand and repressed. For a time many manufacturers molded their bricks in stiff mud or even dry-press machines, but most of them have returned to the old method.

FIRE-CLAYS IN CLEVELAND COUNTY.

NEAR GROVER.—Surrounding the village of Grover is an extensive series of outcrops of a light bluish-gray sandy clay of variable depth and nature. In some pits it shows its residual character beyond a doubt, but at other points, if of residual origin, it appears to have been sorted over and compacted by water action. Two companies have mined this clay, the Grover Brick Company and the Powhatan Clay Manufacturing Company of Richmond, Va.

The former company has one pit in a hollow along a stream three quarters of a mile due S. W. of Grover station. The upper three feet are loam with lumps of red clay, and under this come 6 feet of bluish-white sandy clay (No. 43). The Grover Brick Company make their white fire-brick from this.

A sample of this (No. 43) shows it to be a gritty, fine to coarse, dense, tough clay, with abundant coarse quartz grains. It slakes slowly to irregular grains and scales.

The addition of 32% of water gave a workable mass of moderate plasticity. This paste shrunk 10.6% in drying and 6% in burning, giving a total shrinkage of 16.6%. The average tensile strength of the air-dried briquettes was 38 lbs. per square inch with a maximum of 42 lbs.

Incipient fusion occurs at 2100° F., vitrification at 2300° F., and viscosity at 2500° F. The clay burns white at incipient fusion, but light buff at higher temperature.

The white-burned brick made from this clay are sold as fire-brick. The composition of the clay is as follows:

Analysis of Fire-clay (No. 43), Grover Brick Co.'s Eskridge pit.

Molsture	.76
Silica (total)	68.28
Alumina	18.83
Titanium oxide	.27
Ferric oxide	2.60
Lime	.70
Magnesia	.13
Alkalies	2.29
Water (loss on ignition)	6.47
Total	100.33

Clay substance	46.99
Free sand	53.30
Total fluxes	5.72
Specific gravity	2.57

About 500 feet N. E. of the preceding is a second pit belonging to the Powhatan Clay Manufacturing Company of Richmond, Va. It is seven feet deep. They encountered the same bluish-white sandy clay, and at the bottom of the excavation found considerable dense, fine-grained plastic clay.

The bottom clay (No. 44) which they mine was sampled and tested in order to determine its difference from the more sandy and commoner clay. It is a very plastic clay and freer from grit than the other. It slakes slowly and required the addition of 28% of water to give a workable mud, which shrunk 8% in drying and 5% in burning, giving a total shrinkage of 13%. The average tensile strength of the air-dried briquettes was 39 lbs. per square inch with a maximum of 45 lbs.

Incipient fusion occurs at 2100° F., vitrification at 2300° F., and viscosity at 2600° F. The clay burns to a yellowish-white body.

The analysis of the clay yielded as follows:

Analysis of Fire-clay (No. 44), Powhatan Clay Mfg. Co., S. W. of Grover.

Moisture	1.29
Silica (total)	53.07
Alumina	29.54
Ferric oxide	1.27
Ferrous oxide	1.00
Lime	0.15
Magnesia	0.14
Soda	0.87
Potash	1.28
Water (loss on ignition)	9.93
Total	98.54
Clay substance	61.99
Free sand	36.55
Total fluxes	4.71
Specific gravity	2.24

The bricks made from this clay have the reputation of being free from discoloration. This is due partly to the low iron percentage, and partly to the fact that they are burned hard enough to oxidize the ferrous iron and prevent its being brought to the surface of the brick afterwards in solution and oxidized there to ferric oxide.

The brick have had an extended use in many of the eastern cities.

The clay (No. 45) in the other pit of the Powhatan Clay Manufacturing Company, one-half mile east of Grover (see Plate V, fig. 2,

p. 59), is more like sample (44) from the pit of the Grover Brick Company.

It is a mixture of fine and coarse white clay with abundant sand grains and much mica. In water it slakes very slowly. Thirty-one per cent. of water added to it gave a workable paste, which was lean and gritty and shrunk 4% in drying and 4.5% in burning, giving a total shrinkage of 8.5%. The average tensile strength of the air-dried briquettes was 31 lbs. per square inch with a maximum of 35 lbs. per square inch.

Incipient fusion occurred at 2150° F., vitrification at 2350° F., and viscosity at 2550° F. The clay burns to a yellowish-white.

Its composition is shown by the following analysis:

Analysis of Fire-clay (No. 45), Powhatan Clay Mfg. Co., ½ mile E. of Grover.

Molsture	.95
Silica (total)	64.13
Alumina	22.35
Ferric oxide	1.95
Lime	.10
Magnesia	.22
Alkalies { Soda	.99
{ Potash	1.81
Water (loss on ignition)	5.98
Total	98.48
 Clay substance	46.88
Free sand	51.60
Fluxes	5.07
 Specific gravity	2.51

There are two more openings in the same deposit a short distance south of Grover. These clays around Grover are all good semi-refractory clays, and they make an excellent yellowish-white brick; but their chief use up to the present time has been for the manufacture of light brick. These are molded on stiff-mud auger machines and repressed.

The pit from which the residual clay No. 45 came is shown in fig. 2.

FIRE-CLAYS IN GUILFORD COUNTY.

POMONA CLAY BANK.—The Pomona Terracotta Company has a deposit of white, very sandy, coarse-grained clay on its property which is used for the manufacture of fire-brick. Judging from the angular grains in its substance, as well as the abundance of prominent mica scales, it is probably a residual deposit which has been somewhat altered by wash. It occurs on the south side of North Buffalo creek and just

east of the company's new factory. The available portion of it is three feet thick, for it then changes into a very sandy clay which possesses exceedingly low plasticity. The upper clay slakes very slowly to a granular, gritty mass. It required 26% of water to make a workable paste out of it, and this was lean. This paste shrunk 10% in drying and 2% additional in burning, giving a total shrinkage of 12%. Air-dried briquettes made from this paste had an average tensile strength of 47 lbs. per square inch and a maximum of 49 lbs. per square inch.

Incipient fusion occurs at 2150° F., vitrification at 2350° F., and viscosity at 2550° F.

The clay burns red or buff, depending on the intensity of firing and oxidizing condition of the fire. Its chemical composition is as follows:

Analysis of Fire-clay (No. 25), Pomona Terracotta Works.

Moisture	.98
Silica (total)	70.45
Alumina	17.34
Ferric oxide	3.16
Ferrous oxide	.33
Lime	.25
Magnesia	.22
Alkalies	.70
Water (loss on ignition)	6.63
Total	100.06
Clay substance	48.26
Free sand	51.50
Fluxes	4.66
Specific gravity	2.55

The under clay (25a) is a very siliceous white clay that slakes slowly and completely to irregular grains.

Thirty-three per cent. of water added to it gave a workable but very lean mass which shrunk 3% in drying and 3% in burning, giving a total shrinkage of 6%.

The average tensile strength of air-dried briquettes was 14 lbs. per square inch with a maximum of 16 lbs. Incipient fusion occurred at 2200° F., vitrification at 2400° F., and viscosity at 2600° F. The clay burns to a gray buff.

This clay is not used. Attempts have been made to mix it with the sewer-pipe clay, but it would not take the salt glaze. The trouble is probably similar to a case which Prof. E. Orton, Jr., cited to the writer from Ohio, the difficulty lying in the extremely siliceous nature of the clay, which does not possess enough alumina to unite with the silica and salt to give the glaze, which is a silicate of aluminium and sodium.

The composition of this under fire clay is as follows:

Analysis of Clay (No. 25a), under the Fire-clay, Pomona Terracotta Works.

Moisture	1.17
Silica (total)	70.15
Alumina	15.51
Ferric oxide	3.34
Lime	.83
Magnesia	.07
Alkalies	3.75
Water (loss on ignition)	5.14
Total	99.96
Clay substance	39.46
Free sand	60.50
Total fluxes	7.99

There is probably much undecomposed feldspar in the clay, and while the total fluxes are high, the grain is so coarse as to raise the fusing point.

WOODROFFE CLAY BANK.—Thos. Woodroffe, of Greensboro, has a similar deposit of fire-clay about one mile north of the Pomona sewer-pipe works and along the same creek. It is likewise a very gritty, tough, dense, light gray clay, that slakes very slowly. Twenty-eight per cent. of water was required to make a workable mixture. This shrunk 9.3% in drying and 4% in burning, giving a total shrinkage of 13.3%. Air-dried briquettes of the mud had an average tensile strength of 51 lbs. per square inch and a maximum of 56 lbs. per square inch. Incipient fusion occurs at 2100° F., vitrification at 2300° F., and viscosity at 2500° F.

If burned reddish when heated to barely 2100° F., or in reducing fire the clay remained white. This is the condition of the bricks manufactured from this fire-clay at Pomona, but if the clay is raised above 2100° F. and with an oxidizing fire the clay burns buff or red.

The composition of the clay from Woodroffe's bank is shown by the following:

Analysis of Fire-clay (No. 29), Woodroffe Bank.

Moisture	1.43
Silica (total)	71.60
Alumina	15.27
Ferric oxide	3.33
Lime	.17
Magnesia	.21
Alkalies	2.12
Water (loss on ignition)	5.40
Total	99.53
Clay substance	42.83
Free sand	56.70
Total fluxes	5.83
Specific gravity	2.60

This closely approaches the Pomona Sewer-pipe and Brick Co.'s clay in composition.

PIPE-CLAYS IN NORTH CAROLINA.

Clays which are suitable for the manufacture of sewer-pipe should answer the following requirements:

They should be plastic to permit molding without cracking; they should have a tensile strength of 125-150 lbs. The clay should burn to a dense, hard, impervious body, of a red or deep red color. The drying should permit of rapidity, and the ware should not warp or crack in doing so. The same may be said of the burning.

An excess of fluxing impurities may render a clay so fusible that in burning it softens to such an extent as to lose its shape. It is a very common practice therefore to use a mixture of clays, the one fusible to form a bond in burning, the other much less so to preserve the shape of the ware. This is done at Pomona, for example.

There should be a considerable but not excessive percentage of silica in the clay for the salt vapors to unite with and form the glaze. An excess of silica is detrimental, however, to the formation of a good glaze, for the latter is a silicate of sodium and aluminium, and consequently if there is an excess of silica and lack of alumina, a poor glaze, or perhaps none at all, may form. This is probably the case with the under fire-clay at Pomona, which for a while was mixed in with the pipe-clay.

MANUFACTURE OF SEWER-PIPE AND TILE.

If shale or hard clay is used it has to be first ground in a dry pan, but with soft clays they can be put directly into the wet pan or chaser mill, which in a few minutes tempers each charge rapidly and thoroughly. (Plate VI, fig. 2.)

This method of tempering is far more thorough and quicker than a pugmill, although requiring more power.

The tempered clay is generally taken to the upper story of the factory by means of bucket elevators and discharged into the clay cylinder of the sewer-pipe press. (Fig. 3, p. 87, and Plate VI, fig. 1.)

The press (fig. 3, page 87) consists of two cylinders, an upper steam and a lower clay cylinder, and the ratio of their diameters is generally as 3 : 1. The clay cylinder is filled with clay, and the piston then forced downwards by the piston of the steam cylinder above, the piston rod of the two being continuous. This forces the clay out through the die at the bottom. When the clay in the form of a pipe has issued to the proper distance, the machine is stopped. If of small diameter the pipe is sometimes simply broken off, but for large pipe and usually small ones the pipe is cut off close to the mouth of the die either by means of a wire or else by an automatic knife edge located within the die.



FIG. 1.—PRESS FOR SEWER-PIPE, TILE, AND HOLLOW BRICK.



FIG. 2.—CHASER MILL FOR TEMPERING CLAY FOR SEWER-PIPE.

15-00000-08

100

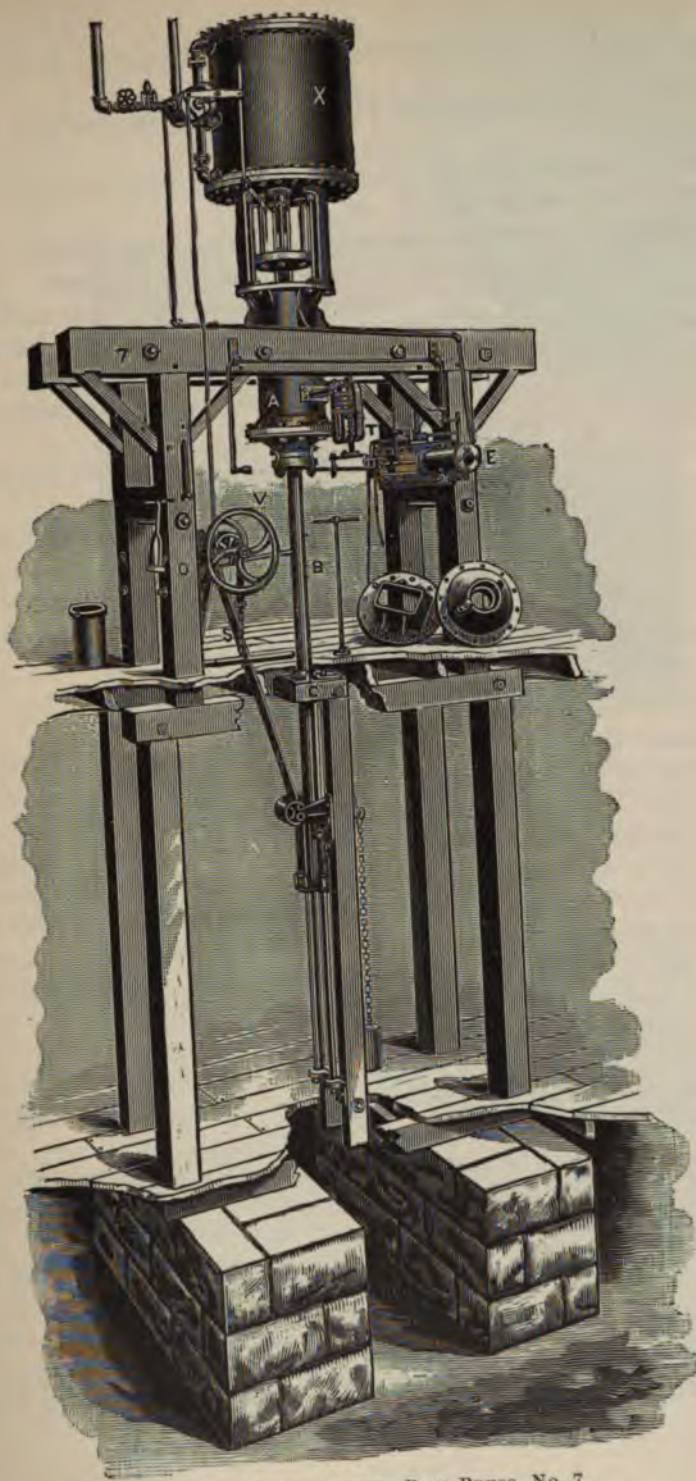


FIG. 3.—VAUGHN SEWER-PIPE PRESS, NO. 7.
60 inch Steam Cylinder, 36 inch Clay Cylinder.

The edges of the pipe are trimmed and the pipe are then set on the drying floor.

Small diameter pipe can be dried comparatively fast, but large ones must be dried very slowly.

Sewer-pipe are usually burned in circular kilns of down-draft pattern, which are from 16-25 ft. (rarely more) in diameter. The pipes are set on top of each other, and when there are several sizes they are nested. Figure 1 of Plate VII shows a circular down-draft kiln.

The burning can proceed quite rapidly on account of the thinness of the ware. The salt is added to the fires when the temperature of the kiln has reached its maximum.

Sewer-pipe should be free from blister, cracks and other defects. They should also be straight.

Elbows and Y's are made by molding the clay in plaster molds, or in the case of Y's and T's straight pieces of pipe are sometimes trimmed to fit together in the desired shape, and the parts cemented by slip. They have to be dried more slowly. Sewer-pipe are made from 2 to 2½ ft. in length, and in diameter from 3-30 inches.

GUILFORD COUNTY.

POMONA TERRACOTTA Co.'s WORKS.—The Pomona Terracotta Company has its works and clay pits at Pomona, three miles west of Greensboro. The clays occur in the bottom of the flat valley along both sides of North Buffalo creek, and are practically of two kinds, a plastic pipe-clay, and a white quartzose clay, called a fire-clay. The pipe-clay is said to occur only on the north side of the creek and the fire-clay on the south side. This is true for the sewer-pipe company's pits, and they also claim it to hold true at other points above and below them on the creek. There are four pits opened up in the pipe-clay. In the first, or that nearest to the factory, there are five feet of dark clay, and two feet of red. The material from this pit furnishes one-half of the sewer-pipe mixture. That in the second pit is similar to the lower clay in the first, but is said to shrink less in burning.

The upper red in the first pit (No. 27) is a lean, gritty clay, which required the addition of 30% of water to make a workable paste. In water the clay slakes quickly to scaly fragments. The clay shrinks 10% in drying and 6% in burning, giving a total shrinkage of 16%. The average tensile strength of the air-dried briquettes was 59 lbs. per square inch, with a maximum of 67 lbs. per square inch. Incipient fusion occurs at 2000° F., vitrification at 2150° F., and viscosity at 2300° F. The clay burns to a brownish red. Its composition is as follows:



FIG. 1.—CIRCULAR DOWN-DRAFT KILN FOR TILE, &c.



FIG. 2.—TUNNEL DRYERS USED IN BRICK MAKING.
(See page 28.)

Analysis of upper Pipe-clay (No. 27), Pomona Terracotta Co.

Moisture	2.05
Silica (total)	54.28
Alumina	22.27
Ferric oxide	8.45
Ferrous oxide	1.33
Lime	.45
Magnesia	.18
Alkalies	.60
Water (loss on ignition)	10.50
Total	100.11
Clay substance	67.57
Free sand	32.51
Fluxes	11.01
Specific gravity	2.50

The color of the fresh clay is evidently due to the high amount of hydrated ferric oxide or limonite.

The under clay (No. 26) from this same pit is also a gritty clay, but more plastic. It slakes slowly to scaly fragments. Forty per cent. of water was required to make a workable mass, which shrunk 10% in drying and 6% in burning, giving a total shrinkage of 16%. The air-dried briquettes made from this material had an average tensile strength of 86 lbs. per square inch and a maximum of 103 lbs. Incipient fusion occurred at 2050° F., vitrification at 2250° F., and viscosity at 2450° F.

The clay burns red. Its composition is shown by the following analysis:

Analysis of under Pipe-clay (No. 26), Pomona Terracotta Co.

Moisture	1.53
Silica (total)	58.73
Alumina	23.94
Ferric oxide	3.71
Lime	.05
Magnesia	.09
Alkalies	1.25
Water (loss on ignition)	9.80
Total	99.10
Clay substance	65.70
Free sand	33.40
Fluxes	5.10
Specific gravity	2.52

The clay in the second pit (No. 28) is a gray, gritty clay with numerous quartz grains, tough, moderately fine-grained, and slakes slowly to irregular granules.

It required the addition of 33% of water to produce a workable mass, which, however, was quite plastic, but did not feel as plastic as the tensile strength would suggest it to be. This mixture shrunk 8% in drying and 3% in burning. The average tensile strength of the air-dried briquettes was 145 lbs. per square inch, with a maximum of 160 lbs. per square inch. Incipient fusion occurred at 2000° F., vitrification at 2200° F., and viscosity at 2400° F.

The clay analyzed as follows:

Analysis of Pipe-clay (No. 28), 2nd pit Pomona Terracotta Co.

Moisture	2.20
Silica (total)	70.75
Alumina	13.87
Ferric oxide	5.01
Lime	.82
Magnesia	.29
Alkalies	1.15
Water (loss on ignition)	5.00
Total	99.09
Clay substance	39.40
Free sand	59.70
Fluxes	7.27
Specific gravity	2.51

As these three clays serve different purposes in the manufacture of the sewer-pipe, it may be well to compare them.

No. 26. Good plasticity.

No. 27. Gives a better red in burning, and vitrifies at lower temperature.

No. 28. Shrinks less and has better bonding qualities. The characters are summed up in the following table:

Comparison of Pipe-clays, Pomona Terracotta Co.

No. of the Sample.	Feel.	Shrinkage.		Tensile Strength.		Fluxes.	Temperature in F. Degrees.		
		Drying.	Burning.	Av.	Max.		Incipient Fusion.	Vitrification.	Viscosity.
26	Plastic	10%	6%	86	103	5.10%	2050°	2250°	2450°
27	Lean	10%	6%	59	67	11.07%	2000°	2150°	2300°
28	Very plastic	8%	3%	145	160	7.27%	2000°	2200°	2400°

The clay as it is mined is thrown into cars which are run to the foot of an incline up which they are drawn by a cable to the factory. The clay mixture is put through the usual chaser mill, each charge being tempered about four minutes. It is then carried on an endless belt to the pipe press. In their old building the company has Barber sewer-pipe presses, and Penfield presses in the new works. There are several

stories of slatted drying floors in each of the two factories, and the heat is supplied by coils of pipe on the lower floor. The diameters of sewer-pipe made are the usual ones up to 24 inches in diameter, inside measure. A second grade of sewer-pipe of the same sizes, manufactured here, is now used largely as a substitute for stone culverts at public road crossings. And in addition to these the company manufactures the following: Terracotta well tubing, 10 to 24 inches inside diameter, and 2 feet long; terracotta chimney flues; and farm drain tile $2\frac{1}{2}$ to 12 inches in diameter.

The burning is done in circular down-draft kilns, 26 ft. in diameter and $8\frac{1}{2}$ ft. high, with inclined grate bars in the fire-places. Soft clinker coal is used for fuel. There are 12 kilns altogether, with one stack for two kilns. (See Plate I, frontispiece, for a general view of the works.)

Flue linings and semi-fire-brick are also made and burned in the same kilns.

The company has an abundance of available clay, as it controls much land bordering the North Buffalo creek and has exploited the clay beds to a considerable extent. It has a complete modern plant, having recently more than doubled its capacity, and is turning out some excellent material.

CHAPTER VIII.

BRICK-CLAYS AND BRICK MANUFACTURE.

GENERAL CHARACTER OF BRICK-CLAYS.

Clays suitable for the manufacture of common brick are so widely distributed in North Carolina that it is hardly necessary to say more here than to refer to the detailed descriptions of the more important occurrences.

In North Carolina two kinds of clay are used:

1. Residual clays.
2. Sedimentary clays.

The residual clays are to be found all over the Piedmont plateau and mountain regions of the state, and their thickness depends on the depth to which the rocks have disintegrated, and also on the slope of the land, for on steep slopes the material is rapidly washed away. Residual clays are usually impure. Those around Greensboro, which are the most worked, showed from 8-12% total fluxes. Owing to the high percentage of undecomposed mineral matter in some of them, they are generally gritty, sandy, and possess little plasticity. They frequently absorb a large amount of water in molding, which they have to give off again in drying, with the consequent danger of checking; this is especially apt to happen when the soft-mud process of hand-molding is used. Owing to their coarseness of grain the residuals do not fuse incipiently under 2000°-2100° F., while the sedimentary clays generally reach the same condition at 1900° F. As very few of the smaller brickmakers reach a temperature of over 1950° F. in burning, the brick are generally underburned, porous and weak.

It has been noticed that when these clays are molded in a steam-power machine, especially a stiff-mud machine, which requires less water to be added to the paste, the resulting brick is smoother and denser. Having less water, it shrinks less in drying, and consequently there is less danger of cracking. The use of some permanent form of kiln also gives better results, as the heat can be better regulated.

The sedimentary clays are found underlying terraces along the rivers or else in the valley bottoms, where they represent the accumulation of clay sediments in lakes or ponds. These clays are far preferable to the residual ones, for they burn dense at a lower temperature; they are more plastic, smoother, have greater tensile strength, and generally burn to a better color than the residual clays.

REQUISITES OF BRICK-CLAYS.

The more impure clays are generally used for the manufacture of building brick. They should burn to a good red color, preferably at a temperature not greater than 2000° F. or 2100° F. They should have enough fluxes to cement the particles to a hard and dense body at the above temperature. From 5-7% of iron is desirable, as this amount has generally been found to exert the best coloring action. A large amount of lime is undesirable, for it brings the temperatures of fusion and incipient vitrification too close together, although Seger has shown that with care a good brick may be made from a clay containing 20-25% of calcium carbonate. Its tendency, as previously stated (chemical properties of clays), is to lessen the shrinkage. If brick-clays contain lime, it should be finely and evenly disseminated, for if in lumps, these are apt to split the burned brick (see p. 21).

Sand seems generally to decrease the plasticity and tensile strength, whether present in coarse grains as in the laminated black clay on the Cape Fear river at Prospect Hall, or in a finely divided condition as in the kaolin four miles west of Troy. It also diminishes the shrinkage to a variable extent. Indeed, sand is sometimes added to very plastic clays to facilitate molding and decrease the shrinkage in drying and burning. It should be borne in mind, however, that it is harmful to go to the other extreme and add too much sand, for the tendency is to produce a weak, porous brick, especially if hand-molded.

Fine-grained clays and very plastic ones generally require slow drying. The reason for this is that on account of the smallness of the pores the moisture cannot escape so readily, and the outer portion of the brick dries and shrinks quicker than the interior. The result is cracking. Rapid drying may be prevented somewhat by adding salt water to the clay; this is a common practice in portions of Missouri.¹

Fine-grained clays very often have to be heated slowly in the early stages of burning, although in the case of fine-grained clays with an abundance of fine sand they can generally be heated rapidly, so far as the North Carolina clays are concerned.

The range of the various constituents in the North Carolina brick-clays is as follows:

Range of Constituents in North Carolina Brick-Clays.

	Range.	Average.
Silica	52-70	60.00
Alumina	13-28	18.00
Ferric oxide	1.5-11.5	6.00
Lime	0.10-2.5	0.60
Magnesia	0.10-1.5	0.40
Alkalies	0.20-4.5	2.00
Water	4-12	7.00
Total fluxes	3.5-17.5	9.00

¹ Mo. Geol. Survey, XI, p. 481.

This is about the usual composition of brick clays, with the exception of lime and magnesia, which are somewhat low.

METHODS OF BRICK MANUFACTURE.

All clay when made into building brick has to go through the following stages:

1. Preparation (crushing or tempering, or both).
2. Molding.
3. Drying.
4. Burning.

Various methods may be used in each stage of the manufacture, and this is especially the case in molding, and, therefore, four methods of manufacture are generally recognized, according to the type of machine used to shape the clay. These four processes are:

1. Soft-mud.
2. Stiff-mud.
3. Semi-dry press.
4. Dry press.

Each of these processes has certain advantages, and its applicability depends on the character of the clay, capacity desired, and capital available.

SOFT-MUD PROCESS.

In North Carolina this is the one most generally used. It is adaptable to almost any clay, and requires the least amount of capital.

TEMPERING THE CLAY.—The clays used are generally soft ones, such as require no grinding. They are first tempered with water. This is done either by throwing the clay into a large rectangular pit behind the molding machine, pouring water over it and allowing it to soak, or else tempering it in ring-pits. These consist of circular pits 15-20 feet in diameter and 2-3 feet deep. In each pit there revolves a large iron wheel attached to a post in the centre, and so geared that it travels back and forth from the centre to the circumference of the pit as it travels around. The clay is shoveled into the pit, water poured over it and the mass allowed to soak for 12 hours, and it is then mixed by the wheel for about six hours more. This is by far the best method of tempering clay for the soft-mud process, for it mixes the clay into a homogeneous mass, which is something a soak pit does not do.

Many small manufacturers in the South have a rather crude arrangement for tempering their clay. It consists of a vertical rectangular box, in which there is set an upright shaft with cross-arms. The clay is thrown in at the top, and by the revolution of the shaft, operated by horse-power, it is forced slowly downward and out at the bottom.

Pugmills are sometimes used in connection with soft-mud machines, but are more frequently used in connection with the stiff-mud process, and will be described under that head.

MOLDING THE BRICK.—The clay is molded by hand or in machines operated either by steam or horse-power. When the clay is molded by hand it is generally tempered somewhat softer, often too much so. A wooden mold is used. The molder takes a chunk of clay from his supply on a table near him, and forming it roughly he lifts it up and then throws it downward into the mold, which has been previously sanded on the inside to prevent the clay adhering. The mold is then reversed onto a pallet, the brick drops out and is carried off by a boy, the "off-bearer," and placed on the yard to dry.

A man can mold about 2500-3000 bricks per day by this method.

The day's work of molded brick, which have been spread out on the yard to dry, are turned on edge at the end of the day to permit equal drying. Sometimes a boy goes along the rows of brick and, with a flat board fastened to the end of a stick, stamps the brick in order to square them up in case the clay was too wet to hold its shape.

Hand-molding is a cheap method as far as cost of plant is concerned, but the capacity is small. Hand-made bricks are generally porous and light, as the clay receives little pressure in molding, but they are homogeneous in structure, and when hard-burnt are usually strong.

The celebrated Philadelphia red front brick were for a long time molded by hand and then re-pressed.

When soft-mud brick are molded by machine the clay is fed into the upper end of a rectangular box, which is really a vertical pugmill. The clay passes downward and is forced into a six-brick mold at the bottom; the latter, as soon as filled, being thrust out. Such machines have a capacity of about 20,000 brick per day. It requires from 5 to 7 men to operate one of these machines, that is, a shoveler, mold-sander, mold-lander, who receives the mold and trims off the superfluous clay, and two or three off-bearers to spread the brick on the yard.

DRYING.—Soft-mud bricks are generally dried in the sun. As this method requires considerable space, especially when large capacity is required, it is sometimes found desirable to dry the brick on pallets set one above the other on racks. This increases the drying capacity, avoids handling until the brick are set in the kiln, and there is no loss from washed brick. The drying takes a little longer.

BURNING.—Soft-mud bricks are usually burned in scove-kilns; that is, they are piled up in rectangular masses 35-40 courses high, and open spaces or arches are left at intervals in the bottom of the pile, these arches running through the mass.

The exterior of the "kiln" is daubed over with mud, and one or two

courses of brick, called the "platting," are laid flatside down on the top of the kiln to keep the heat in. Fires are then built in both ends of the arches, and the interior of the kiln is gradually heated to the desired temperature.

Burning is the most important step in the manufacture of brick. It is important that the heat should be raised slowly during water-smoking and also while the combined water is being driven off, and, furthermore, that the temperature should be distributed as evenly as possible throughout the kiln, for it is a common fault at many of the smaller yards that the arches are almost melted while the upper courses can sometimes barely be called salmon brick. In this connection there may be mentioned the practice followed by some manufacturers of adding coal-dust to the brick to be placed in those parts of the kiln which do not receive sufficient heat. In burning, the coal-dust in the brick ignites and supplies additional heat where it is needed. The coal dust is added in the proportions of one bushel to clay for 1000 brick, and is added to the clay before it is tempered. Wood is the fuel commonly used in burning soft-mud brick. The arches are often closed by iron doors, and these should never be omitted, for a flood of cold air rushing into a mass of red-hot brick is sure to do damage.

If the heat is raised too rapidly, the outer part of the brick shrinks and becomes dense before the ferrous oxide of the interior has been converted to the ferric oxide, and a black core is generally to be seen in such cases; unequal shrinkage and consequent cracking also results from the same cause.

STIFF-MUD PROCESS.

PREPARATION OF THE CLAY.—This method of making brick is applicable to either shales or clays. In the case of the former they generally have to be prepared by grinding them in a dry pan. This consists of a large circular revolving iron pan about 9 feet in diameter (fig. 4, p. 97). In this there are two iron rolls weighing 3000-4000 pounds each, and which revolve by friction against the bottom of the pan. The outer part of the bottom is perforated by slits one-fourteenth to one-sixteenth inch diameter, according to the fineness to which the material is to be ground.

For softer shales and tough clays a disintegrator is used.

Many of the North Carolina manufacturers pass their clay first through a pair of rolls, but as in most instances where these are used the clay contains no stones and needs only tempering, the advantage of using the rolls is not apparent.

TEMPERING THE CLAY.—For a stiff-mud machine the tempering is generally done in a pugmill. This consists of a horizontal trough in

which there revolves a shaft bearing knife blades set at a small angle. The clay and water are fed in at one end and as they are pushed forward towards the other end, where they are discharged into the machine, they become thoroughly mixed. This is of considerable importance, for in the case of laminated clays their structure should be destroyed by thorough mixing. Pugmills are generally six or eight feet long, and the longer the better. A wet pan gives better results than a pugmill, for it not only crushes a soft clay but tempers it thoroughly.

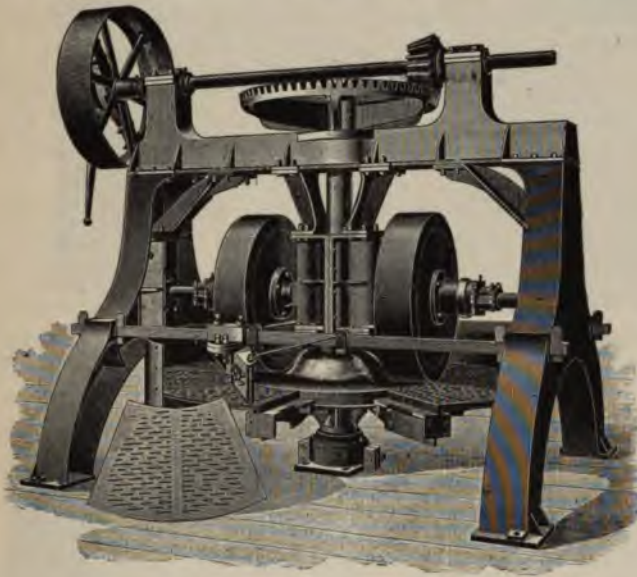


FIG. 4.—DRY-PAN CRUSHER.

There are many stiff-mud auger machines put on the market which have a pugmill about three feet long, and many manufacturers have bought them, probably for cheapness. In almost every case they give dissatisfaction unless the clay is thoroughly tempered before being molded in them, for the pugmill is entirely too short to be effective.

MOLDING.—Two types of stiff-mud machines are used, the plunger and the auger. In both the clay is discharged in the form of a rectangular bar. The plunger machine is intermittent in its action; the auger is continuous, sometimes intermittent, and perhaps the favorite method. The bar of clay may be $2\frac{1}{2} \times 4$ inches or 9×4 , according as the brick is to be an end-cut or side-cut one.

The capacity of an auger machine is usually from 50,000 to 70,000 per day, but it may be less or more. Auger machine bricks are apt to be laminated, which gives a shelly structure to the brick. Some clays

show this more than others, and the same clay may show more laminations when side-cut than end-cut. Very plastic clays usually laminate the most.

Auger machine brick are often repressed, especially if to be used for paving or fronts. If pressed brick are to be made it is important to test the clay on different stiff-mud machines first to determine which works the best. Plate VIII shows an auger end-cut brick machine (fig. 1), and a re-pressing machine (fig. 2).

The bar of clay as it is cut up into bricks is received on a belt which carries the brick to the repressing machines or else to the "off-bearers," who place them on cars which are run into a drying tunnel. Stiff-mud brick are stiff enough when molded to permit of their being piled 6 or 8 courses high on the drying cars without crushing out of shape.

Re-pressing sharpens the form of the brick, but adds considerably to the cost of manufacture.

The brick, when piled on the cars, are run into long tunnels, which are heated by steam, coal or oil (see Plate VII, fig. 2, p. 88). Recently successful experiments have been made towards utilizing the waste heat from the cooling kilns for drying the brick. The rapidity of the drying varies from 20 to 50 or 60 or more hours according to the clay. Rapid drying cracks many clays.

Few stiff-mud brick are dried in the sun.

BURNING.—This is done either in up-draft or down-draft kilns. The *up-draft kilns* generally have permanent side walls, the ends and top being closed up with brick and those at the ends daubed with mud. Such kilns usually have a capacity of 150,000 to 200,000. The up-draft kilns are cheaper to construct than down-draft ones, but there is a greater percentage of salmon brick obtained. Figure 1 of Plate X (p. 101) shows an up-draft kiln used at the state penitentiary at Raleigh. This has permanent side walls, which are braced by brick offsets.

Continuous kilns are sometimes used. This is the ideal method of burning brick and the cheapest. They have been used most successfully abroad and are gradually coming into extended use in this country. The continuous kiln consists essentially of a long chamber of oval form, which is divisible into compartments by means of temporary partitions. Each compartment has one or two entrances for wheeling the green brick in and the burned brick out. There are four or more openings, covered by caps in the top of each chamber for feeding the fuel, as will be mentioned later.

In the walls of the kiln are a series of flues connecting the chambers with the chimney, and also by means of dampers, making connection possible between any two chambers. Each chamber has a capacity of 20,000 to 22,000 brick, and in setting them vertical spaces are left under



FIG. 1.—STIFF-MUD AUGER END-CUT BRICK MACHINE.

Shows a bar of clay issuing from the die of the machine. This is cut across by a wire at proper intervals, thus dividing it into brick.



FIG. 2.—RE-PRESSING BRICK MACHINE.

The brick to be re-pressed are brought from the moulding machine on a belt (as shown in the foreground), from which they are taken by a workman who places them, two at a time, into the machine.

THE NEW YORK
PUBLIC LIBRARY

ASTOR, LENOX
TILDEN FOUNDATIONS

NEW YORK
PUBLIC LIBRARY

ASTOR, LENOX
TILDEN FOUNDATIONS





FIG. 1.—INTERIOR VIEW OF A CONTINUOUS BRICK-KILN.



FIG. 2.—EXTERIOR VIEW, CONTINUOUS BRICK-KILN.

the charging holes in the roof. As each chamber is filled the temporary (often paper) partition between it and the next one is put up, the object of this being simply to prevent the draft from passing straight through the whole kiln.

After each chamber is filled the two entrances are bricked up, leaving a charging space, which is covered by an iron door. The kiln is started by building a fire in the doorway of the first chamber and gradually heating it up to the desired temperature. Coal slack is also charged through the openings in the top. Many manufacturers no longer use the top openings, but feed all the fuel through the doorways.

The important principle of the continuous kiln is that the heat from this burned chamber is conducted into the next one either through the flues in the wall or else through sheet-iron pipes placed to connect the roof openings. In this way the heat raises the temperature of the next chamber, so that less fuel need be used. When the kiln is once started it takes from 200-300 pounds of fuel per 1000 brick.

The heat from a burning chamber cannot as a rule be carried safely through more than three or four chambers before taking it off to the chimney. The reason for this is that the hot-air collects moisture from the brick in these chambers which are being heated up; it will easily be seen that if carried through too many chambers the air will lose so much heat that instead of gathering moisture it will begin to deposit it on the brick.

It is sometimes necessary to aid the draft of a continuous kiln by means of a small fan. The number of chambers in the kiln depends on the size of the yard and available capital.

Continuous kilns are used in this country for burning common and front brick, paving brick and fire-brick.

No continuous kilns are in use in North Carolina, so that the illustrations shown are from one at the Catskill (N. Y.) Paving-Brick Works. Fig. 1 of Plate IX shows the interior view of the kiln, which is empty, while fig. 2 of the same plate shows the exterior view.

DRY-PRESS PROCESS.

This method is applicable to a variety of clays, but not to very sandy ones, which have little cohesive nature. The advantages of it are wide range of character permissible in clays used, the brick made are sharp-edged and smooth, and the green brick can generally be set directly in the kiln.

The disadvantages of this method are, the necessity of weathering the clay, increased cost of plant, and limited capacity.

Dry-press brick when properly burned are as strong as other brick, but if underburned they are easily affected by the weather.

PREPARATION OF THE CLAY.—The clay for making dry-press brick is generally weathered first. This is accomplished by piling the clay up under large sheds or spreading it out over the ground in a layer one to two feet thick. If possible, it is frequently best to allow the clay to weather for several months or even longer, depending on the nature of the material. By this weathering the moisture becomes evenly distributed through the clay, the frost breaks it up and the decay of organic material by the disengagement of carbonic acid produces the same effect. The iron compounds may also become further oxidized. Clays weather more actively in winter than in summer.

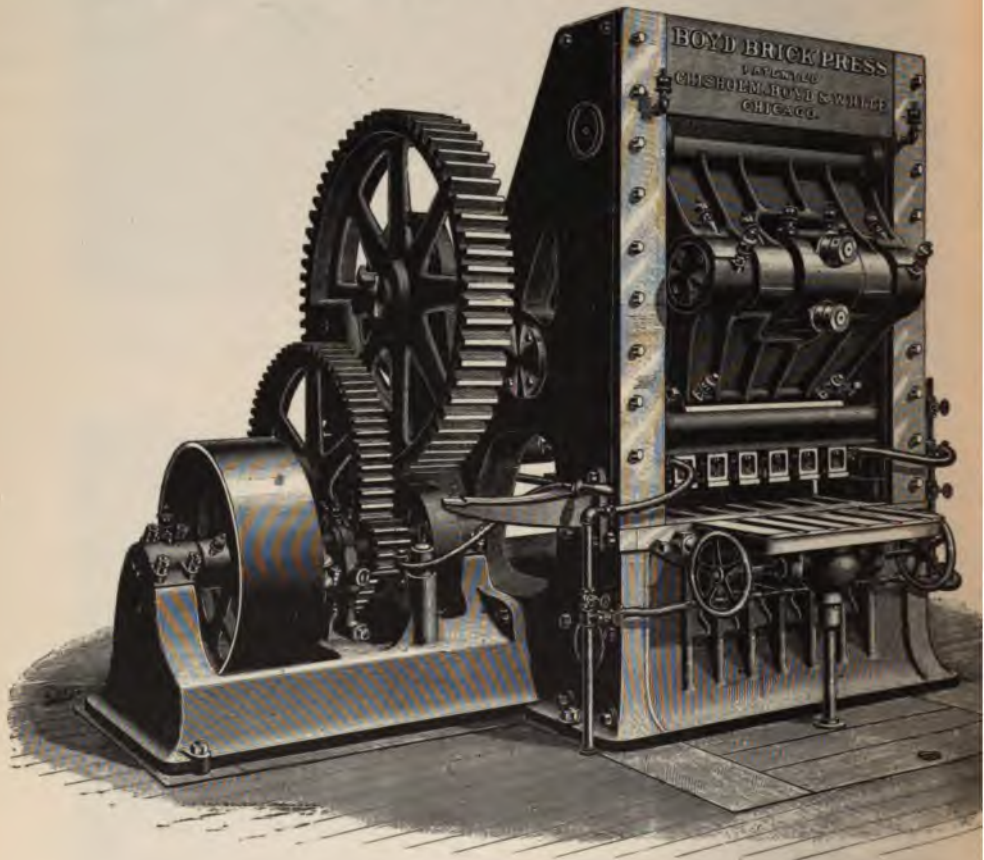


FIG. 5.—DRY-PRESS BRICK MACHINE.

When ready for use the clay is first pulverized, usually in a centrifugal disintegrator of the Steadman type, and then passed through a screen with meshes varying from one-eighth to one-sixteenth inch,

THE NEW YORK
PUBLIC LIBRARY
ASTOR LENOX
TILDEN FOUNDATION

THE NEW YORK
PUBLIC LIBRARY
ASTOR LENOX
TILDEN FOUNDATION



FIG. 1.—UP-DRAFT BRICK-KILNS, FOR BURNING COMMON BRICK, AT THE STATE PENITENTIARY, RALEIGH, N. C. (See page 98.)



FIG. 2.—DOWN-DRAFT BRICK-KILN, EUDLAY TYPE. (See also page 141.)

the finer mesh being used for front brick. The clay should not contain too much moisture, as otherwise it clogs the screen.

MOLDING THE BRICK.—The dry-press consists essentially of a steel mold box with movable top and bottom. The clay is fed into the mold automatically, and the plunger descends into the mold from above, the pressure being applied by means of a toggle-joint or cam. After the clay is pressed the plunger rises, as does also the bottom of the mold, until the brick is level with the table, on which it is pushed forward by the charger as it advances to refill the mold. The brick are set on hand-cars and carried off to the kilns.

If the clay is very dry the edges are apt to crumble, and the brick will not bear much handling. To avoid this the clay is sometimes discharged from the screen into a pugmill, where it is moistened with steam. This gives a brick with sharper edges and one which bears handling better. The term *semi-dry press* is used when the clay is moistened somewhat.

There are numerous types of dry-press machines, among which may be mentioned those of the Boyd (fig. 5, p. 100), Simpson, Whittaker, and Chambers patterns. The slower the pressure is applied in molding the brick the less air will there be enclosed in it, and the less will be the danger of its bursting by the expansion of the air.

BURNING.—Dry-press brick are burned in either up-draft or down-draft kilns. This process has to be conducted very slowly, for both the drying and water-smoking have to be done in the kiln, and, on account of the dense nature of the brick, the water can only escape slowly. Drying and water-smoking may therefore take from six to eight days. In burning front brick it is important that as few as possible should be exposed to the direct action of the flames. In up-draft kilns the arch brick are generally warped and discolored, while in down-draft kilns the top courses are generally fire-flashed and also discolored from the ashes of the fuel. These top brick are harder burned than the bottom ones, and while useless for front brick, if not cracked they are often desirable for walks or sewers.

The down-draft kiln is preferable for burning front brick, as there is less loss in the form of overburned or underburned brick. Plate X, fig. 2, shows the Eudaly type of down-draft kiln, which is in common use.

CHAPTER IX.

BRICK-CLAY DEPOSITS IN NORTH CAROLINA.

CLAYS IN BLADEN COUNTY.

NEAR PROSPECT HALL.—Following down the Cape Fear river from Fayetteville, after passing Willis creek, there begin to appear large quantities of black clay in the bluffs along the river. One of the best sections is to be seen in a bluff 60 feet high on the property of William Whitted at Prospect Hall (see Plate XI, fig. 1, p. 110).

The upper 20 feet of the bluff are sand and gravel often heavily stained with iron, but the lower forty feet are mostly black clay, roughly separated into three somewhat lens-shaped beds, as follows:

Black, sandy clay, 8-10 feet (field sample No. 11).

Sand and sandstone, 10 feet.

Black, sandy clay, 8 feet (field sample No. 10).

Black clay, 4 feet, exposed at base of bluff (field sample No. 12).

The upper black sandy clay of the section (No. 11) has in places abundant mica scales, and sometimes coarse sand grains. It slakes slowly to large scaly fragments. Pyrite and lignite are both scattered sparingly through the clay, but the pyrite is mostly in small grains. The addition of 38% of water gave a mass that was lean and gritty. This paste shrunk 6% in drying and 8% in burning, giving a total shrinkage of 14%. Air-dried briquettes of this paste had an average tensile strength of 64 lbs. per square inch and a maximum of 77 lbs. per square inch. Incipient fusion occurs at 1900° F., vitrification at 2100°, viscosity at 2300°. It burns to a deep red, dense body.

The composition of this clay is:

Analysis of Brick-clay (No. 11), Prospect Hall.

Moisture	4.50
Silica (total)	56.13
Alumina	17.80
Ferric oxide	5.85
Lime	.10
Magnesia	.79
Alkalies	2.45
Water (loss on ignition)	11.60
Total	99.22
Free sand	27.18
Total fluxes	7.29
Specific gravity	2.34

No. 11 is similar to No. 10, but contains more coarse grit, and the mica scales are abundant. It slakes slowly to large fragments, and required the addition of 22% of water to make a workable paste, which is very lean. This paste shrunk 5% in drying and 8% in burning, giving a total shrinkage of 13%. The tensile strength is very low as indicated by the plasticity, being on the average only 46 lbs. per square inch, with a maximum of 58 lbs. per square inch. Incipient fusion occurs at 2000° F., vitrification at 2150° F., and viscosity at 2300° F. The clay burns to a deep red body.

Its composition is as follows:

Analysis of Brick-clay (No. 10), Prospect Hall.

Moisture	2.80
Silica (total)	63.30
Alumina	15.87
Ferric oxide	5.48
Lime	.27
Magnesia	.21
Alkalies	2.40
Sulphur	1.78
Water (loss on ignition)	8.25
Total	100.36
Free sand	57.30
Total fluxes	10.14
Specific gravity	2.43

The organic matter is noticeable from the loss on ignition which the clay undergoes. The total percentage of fluxes is greater than in No. 11, but their fluxing tendency is more than offset by the sand present.

No. 12 is the best clay of the three, as it contains less sand, mica scales and pyrite. It is also more homogeneous, harder and denser. The sand and mica grains are mostly between the layers of the clay. The clay slakes slowly to large scaly fragments. It soaks up a large quantity of water, and required 40% to make a workable mud that had little plasticity. This mud shrunk 12% in drying and 5% in burning, giving a total shrinkage of 17%. The air-dried briquettes made from this paste had an average tensile strength of 59 lbs. per square inch and a maximum tensile strength of 90 lbs. per square inch. Incipient fusion occurred at 1900° F., vitrification at 2100° F., viscosity at 2300° F.

The composition of the clay is as follows:

Analysis of Brick-clay (No. 12), Prospect Hall.

Moisture	4.26
Silica (total)	55.65
Alumina	20.86

Ferric oxide	5.11
Lime	.30
Magnesia	.64
Alkalies	2.13
Sulphur	1.18
Water (loss on ignition)	9.94
Total	100.07
Free sand	15.05
Total fluxes	9.36
Specific gravity	2.30

The chief objection to these clays is their lean character. They stand rapid heating and burn easily to a dense red body.

If molded into brick, it should be done by machinery that would give them good pressure, and not by hand. The admixture of a more plastic clay would be a still better method to follow.

They might possibly be worked for paving brick.

CLAYS IN BUNCOMBE COUNTY.

PENNIMAN CLAY BANK NEAR EMMA.—Along the line of the Southern R. R., southwest of Asheville, on the road to Murphy, deposits of sedimentary clays are to be found at a number of localities. Their largest development is at Emma, two miles west of Asheville, where considerable quantities of brick are made by W. R. Penniman.

The section exposed in Penniman's bank is as follows:

Upper red clay	4 feet.
Lower gray clay ("fire-clay")	3-10 feet.
Sand	—

The upper clay is tough, gritty, highly colored, and in places seems to grade downward into the under gray clay.

The upper or brick clay slakes quickly to grains of sand and mica and fine aluminous mud.

The addition of 20% of water gave a workable paste of somewhat plastic feel. This paste shrunk 9% in drying and 4% in burning, giving a total shrinkage of 13%. The air-dried briquettes made from this mud had an average tensile strength of 63 lbs. per square inch, with a maximum of 80 lbs. per square inch. Incipient fusion occurred at 2000° F., vitrification at 2200° F., and viscosity at 2400° F.

The clay burns to a good red body. The following is the analysis:

Analysis of upper Brick-clay (No. 59). Penniman's.

Moisture	1.15
Silica (total)	66.27
Alumina	19.95

Ferric oxide	3.16
Ferrous oxide	.67
Lime	.20
Magnesia	.32
Alkalies	1.85
Water (loss on ignition)	6.17
Total	99.74
Clay substance	49.34
Free sand	50.40
Total fluxes	6.20
Specific gravity	2.50

The iron is mostly oxidized, as will be seen from the analysis and also indicated by the color of the clay.

The under clay at this yard goes by the name of fire-clay. It is a coarse-grained clay, full of mica scales and small angular quartz grains. In water it slakes quickly and completely, and on the addition of 28% of water gave a workable and moderately plastic paste which shrunk 7% in drying and 4% in burning, giving a total shrinkage of 11%. The average tensile strength of the air-dried briquettes made from this clay was 58 lbs. per square inch, with a maximum of 60 lbs.

Incipient fusion occurs at 2050° F., vitrification at 2250° F., and viscosity at 2450° F. The clay burns gray buff. The composition of the clay is as follows:

Analysis of lower Brick-clay ("fire-clay") (No. 56), Penniman's.

	Total portion.	Insoluble portion.
Moisture	.80	
Silica (total)	70.68	55.70
Alumina	17.21	.40
Ferric oxide	3.44	.56
Lime	.10	
Magnesia	.07	
Alkalies	2.45	1.32
Water (loss on ignition).....	5.00	
Total	99.73	57.98
Total fluxes	7.16	
Specific gravity	2.48	

From the above analysis we obtain:

Clay substance	41.75
Quartz	54.30
Feldspar.	3.68

This clay is not unlike the bottom clay at Bethania, but contains more free sand. The grains of the latter are mostly quartz, as seen from the rational analysis.

This type of clay is not uncommon in North Carolina, the clays at Grover being of this kind, but they contain less iron. The predominant character, however, is the fine-grained clay substance with the coarse quartz grains scattered through it.

Mr. Penniman uses the upper clay for making common brick and also for re-pressed brick, for it burns to a good red color. The brick are molded in a Sword's machine, dried in the sun and burned in up-draft open kilns with permanent side walls, of 185,000 capacity. The fuel is coal.

The brick made from the lower clay are burned in the same kiln and at the same time as the red clay. They are re-pressed. The chief use of the lower clay brick is for boiler and furnace foundations and for furnaces requiring only a low degree of heat. The bricks are white or yellowish-white, and not burned very hard.

It is probable that a mixture of the upper and lower clay would make a paving brick, although if a more plastic and slightly more fusible clay than the upper one could be mixed with the lower clay, still better results would be obtained. Such clays are to be found in many of the lowlands along the valleys near Asheville.

CLAYS NEAR ASHEVILLE AND BILTMORE.—The French Broad river near Asheville is bordered at several points by broad stretches underlain by clays of good quality for various purposes. Such a deposit has been worked at Biltmore with eminent success, the products being common and pressed brick, drain tile, and paving brick. The deposit has been covered up now to permit land improvements, but the same belt of clay land borders the river at other points.

It should be noted that the methods and machinery used at Biltmore were of the most approved type.

Poor products may result very often as much from carelessness in manipulation and the use of the wrong appliances and methods as in the use of improper clay.

The other brickyards around Asheville are working residual clays for making common brick to supply a local demand.

CLAYS NEAR FLETCHER.—The Buncombe Brick Co. at this locality is engaged in the manufacture of both common, pressed and paving brick. Their main bank is a light gray clay of slightly plastic and somewhat gritty feel. It is fine-grained and slakes slowly. The addition of 25.5% of water was required to give a workable mass, which shrunk 4% in drying and 7% in burning, making a total shrinkage of 11%. The air-dried briquettes had an average tensile strength of 37 lbs. per square inch and a maximum of 40 lbs. per square inch.

Incipient fusion occurs at 2000° F., vitrification at 2200° F., and viscosity at 2400° F.

The chemical composition of the clay is:

Analysis of Brick-clay (No. 65), near Fletcher.

Moisture	1.10
Silica (total)	75.08
Alumina	13.73
Ferric oxide	3.47
Lime	.30
Magnesia	.17
Alkalies	1.48
Water (loss on ignition)	4.65
Total	99.98
Clay substances	45.18
Free sand	55.80
Total fluxes	5.42
Specific gravity	2.41

CLAYS IN BURKE COUNTY.

NEAR MORGANTON.—The clay underlying the terrace along the river two miles west of the town becomes more sandy in character towards the river. A sample from the brickyard of Mr. McDowell along the river had 60% of sand, while along the road, back from the river, there was only 54%.

The clay as exposed in McDowell's brick-clay bank (No. 52) is a loose, sandy, coarse clay, with abundant mica scales and quartz grains. It slakes very quickly and completely to its component grains. The addition of 22% of water gave a lean but workable mud which shrunk 6% in drying and 5% in burning, giving a total shrinkage of 11%.

The average tensile strength of the air-dried briquettes was 56 lbs. per square inch, with a maximum of 83 lbs.

Incipient fusion occurs at 1950° F., vitrification at 2100° F., and viscosity at 2250° F. The clay burns dark red at 2100° F.

The analysis of it gave:

Analysis of Brick-clay (No. 52), McDowell's clay bank.

Moisture	1.80
Silica (total)	67.03
Alumina	16.88
Ferric oxide	6.50
Lime	1.00
Magnesia	1.16
Alkalies	.90
Water (loss on ignition)	4.78
Total	100.05

Clay substance	39.90
Free sand	60.05
Total fluxes	9.56
Specific gravity	2.61

The clay is used for making common brick, but they are molded in ordinary hand-molds and burned barely to incipient fusion; with more care and better machinery a very good brick could be made from it.

Probably there could be found a more plastic clay in the lowlands between the railroad and the North Carolina Insane Asylum.

CLAY IN CLEVELAND COUNTY.

NEAR GROVER.—Occurring in the region around Grover are beds of surface clays which have no connection with the so-called fire-clays previously mentioned (p. 81). At the works of the Cleveland Brick Company just south of Grover, one of these beds has been opened up and consists of an upper bed of tough, red, mottled clay, 6 feet thick, and an under bed of very plastic clay not less than 3 feet thick.

The under clay (No. 46) is a gritty clay with small mica flakes and coarse sand grains. It is slow in slaking. 35% of water was required to give a workable mass that shrunk 9% in drying and 6.5% in burning, giving a total shrinkage of 15.5%. Air-dried briquettes of the clay had an average tensile strength of 98 lbs. per square inch and a maximum of 115 lbs. per square inch. Incipient fusion occurs at 1900° F., vitrification at 2100° F., and viscosity at 2300° F. The clay burns a rather light red.

The analysis of the clay gives:

Analysis of Cleveland Brick Co's. under Clay (No. 46), just S. of Grover.

Molsture	1.18
Silica (total)	61.75
Alumina	23.30
Ferric oxide	3.34
Ferrous oxide	.50
Lime	.27
Magnesia	.25
Alkalies	1.31
Water (loss on ignition)	7.75
Total	99.65
Clay substance	60.62
Free sand	39.05
Total fluxes	5.67
Specific gravity	2.36

The upper clay is far less plastic, but very tough. It also required 35% of water to make a workable paste, which was gritty to the feel and somewhat plastic. This clay shrunk 7.5% in drying and 5% in burning, giving a total shrinkage of 12.5%. The average tensile strength of the air-dried briquettes was 42 lbs. per square inch with a maximum of 51 lbs. Incipient fusion occurred at 1950° F., vitrification at 2150° F., and viscosity at 2350° F. The clay burns red.

The composition of this clay is as follows:

Analysis of Cleveland Brick Co.'s upper Clay (No. 47), just S. of Grover.

Molsture	.63
Silica (total)	65.45
Alumina	20.02
Ferric oxide	4.18
Lime	.25
Magnesia	.29
Alkalies	1.51
Water (loss of ignition)	6.58
Total	98.91
 Clay substance	 47.06
Free sand	51.45
Total fluxes	6.23
Specific gravity	2.61

While the upper clay is not as strong as the lower, still it burns easier to a red brick and shrinks less in burning.

The pit is about 300 feet from the yard, and the clay is hauled in carts. The tempering is done in a long open pugmill of Chambers's manufacture. Molding is done in a Chambers's auger automatic end-cut machine. A pair of rolls were formerly used for breaking the clay, but were found very unsatisfactory. A standard dryer heated by steam-pipes is used. Exhaust steam is used in the daytime and live steam at night.

The brick are burned either in scove kilns or circular down-draft ones. They are 16 feet in diameter, and there is one stack for every two kilns, but Mr. Eskridge is about to put a number of small chimneys on each kiln.

The fire-brick are burned in the circular kiln. They are used for the roof of the roasting furnaces at the Blacksburg (South Carolina) acid works, and wear well. The furnace has a diameter of 20 feet, and the rise from circumference to centre is 8 inches.

The hard red brick are used around the acid works and resist the action of the acid very well.

This clay is not unlike many of the alluvial clays in other parts of

North Carolina, and they show very well the influence of proper working and machinery in producing good results.

CLAY IN CUMBERLAND COUNTY.

NEAR FAYETTEVILLE.—South of the town are extensive beds of sedimentary clays, whose general section involves 2-3 feet of coarse sand underlain by at least eight feet of clay, and sometimes probably more. The clays are best exposed at Poe & Bros.' yard, a half mile south of Fayetteville. The clay as exposed here is a fine-grained, tough, bluish-white clay with frequent thin iron stains, which give it a mottled appearance. In some portions of the bank the clay is very smooth and free from iron stains, and has been used for stoneware. (Plate XI, fig. 2.)

At the south of the pit is a bed of very tough clay, fine-grained and broken by numerous small joints running in every direction. This portion is not used, as it is claimed to be too tough to work.

A sample of the average run of the bank, excluding the top sand and tough clay, which is not used, showed the clay to be a somewhat gritty, medium-grained, tough clay which slakes quickly to grains $\frac{1}{80}$ to $\frac{1}{60}$ in. in diameter. It required the addition of 28% of water to make a workable mud, which felt quite plastic. This mass shrunk 8.5% in drying and 5% in burning, giving a total shrinkage of 13.5%. The air-dried briquettes of this paste had an average tensile strength of 144 lbs. per square inch and a maximum of 175 lbs. per square inch.

Incipient fusion occurs at 1900° F., vitrification at 2050° F., and viscosity at 2200° F. The clay burns deep red.

The chemical composition of the clay is as follows:

Analysis of Poe's Brick-clay (No. 14), $\frac{1}{2}$ mile S. of Fayetteville.

Moisture	2.48
Silica (total)	64.93
Alumina	17.08
Ferric oxide	5.57
Lime	.43
Magnesia	.59
Alkalies	3.85
Water (loss of ignition)	6.58
Total	101.51
Clay substance	53.13
Free sand	45.90
Total fluxes	10.44
Specific gravity	2.55

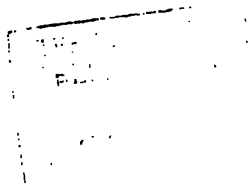
A sample of the so-called "tough" clay was also tested with the following results. It is a dense, somewhat gritty clay which slakes



FIG. 1.—BLACK CLAY ALONG CAPE FEAR RIVER, AT PROSPECT HALL.
(See page 102.)



FIG. 2.—POE BROTHERS' CLAY BANK, FAYETTEVILLE, N. C.



slowly to rounded granules of variable size, mostly above $\frac{1}{16}$ in. Little mica was noticeable. It required the addition of 28.5% of water to make an easily worked paste, which shrank 9.8% in drying and 7% in burning, giving a total shrinkage of 16.8%. Air-dried briquettes of this clay had an average tensile strength of 84 lbs. per square inch and a maximum of 120 lbs. per square inch. Incipient fusion occurs at 1850° F., vitrification at 2050° F., and viscosity at 2250° F. The clay burns deep red, and requires somewhat slow heating to prevent cracking. The composition of the clay as shown by analysis is as follows:

Analysis of the "tough clay" (No. 15). Poe's bank $\frac{1}{2}$ mile S. of Fayetteville.

Moisture	3.23
Silica (total)	58.17
Alumina	20.10
Ferric oxide	7.43
Lime	.60
Magnesia	.77
Alkalies	2.60
Water (loss of ignition)	7.34
Total	100.24
Clay substance	48.00
Free sand	52.15
Total fluxes	11.40
Specific gravity	2.45

The greater toughness of this clay is due to its density.

This "tough clay" could probably be mixed advantageously with the other. As this clay is manufactured into a very good brick, it may be well to mention the method followed. The clay and sand are first dumped into soak pits. From these they are shoveled into a Penfield plunger machine and issue from this onto the cutting table, where they are cut up into brick, the frame carrying the cutting wires being operated by hand-power. The drying is usually done on pallets and proceeds very slowly. The burning is done in permanent side-wall, up-draft kilns, having a capacity of 170,000. Re-pressing the brick has been attended with favorable results.

CLAY IN FORSYTH COUNTY.

NEAR BETHANIA.—The largest brick-making plant in the State is situated at this locality. It is owned by Messrs. Carter and Shepard. (Plate XII, fig. 1, p. 120.)

The clay bank adjoins the yard and consists of a gray clay, the upper portions of which are intermixed with the wash of residual clay from the neighboring slopes. The lower portion, of which there is an

abundance, is much superior to the top mixture, and the two have been tested separately to determine their relative advantages.

The lower clay (32) is tough, somewhat coarse-grained, with grains of quartz and small mica scales. It slakes slowly to grains.

The addition of 25% of water gave a very plastic, workable mass, which shrunk 10% in drying and an additional 5% in burning, giving a total shrinkage of 15%. The tensile strength of the air-dried briquettes showed an average of 127 lbs. per square inch and a maximum of 160 lbs. per square inch.

Incipient fusion occurs at 1900° F., vitrification at 2100° F., and viscosity at 2300° F. The clay burns buff to red, dependent on the temperature.

The composition of the clay is as follows:

Analysis of lower Brick-clay (No. 32), Bethania.

Moisture	.90
Silica (total)	64.39
Alumina	19.11
Ferric oxide	5.39
Lime	.80
Magnesia	.22
Alkalies	1.72
Water (loss on ignition)	7.75
Total	100.28
Clay substance	53.18
Free sand	46.60
Total fluxes	8.13
Specific gravity	2.50

The upper mixture is a lean, stiff, sandy clay which slakes easily to irregular grains and scales. It required 27% of water to give a workable mud, which was lean and gritty to the feel. This paste shrank 8.5% in drying and 6% in burning, giving a total shrinkage of 14.5%. The air-dried briquettes had an average tensile strength of 65 lbs. per square inch and a maximum of 89 lbs. per square inch. Incipient fusion occurred at 2000° F., vitrification at 2150° F., and viscosity at 2300° F. The clay burns to a deep red. Its composition is shown by the following analysis:

Analysis of the upper Brick-clay (No. 33), Bethania.

Moisture	1.85
Silica (total)	55.81
Alumina	20.06
Ferric oxide	11.79
Lime	.33

Magnesia	.16
Alkalies	1.42
Water (loss on ignition)	8.80
Total	100.22
Clay substance	67.44
Free sand	32.78
Total fluxes	13.70
Specific gravity	2.51

The upper clay contains more iron and burns to a deeper red, but does not possess the tenacity or plasticity that the lower clay does.

CARTER AND SHEPARD'S CLAY BANK.—This clay at Bethania is used for brick and drain tile. It is first put through rolls and then a pugmill, after which it is molded in a Steele auger machine. The drying is done either on pallet racks or on heated floors. The brick are burned in a Morrison kiln and are of a deep red color, but full of laminations.

If the clay were prepared more thoroughly, and more of the under clay used, it would probably give better results.

CLAY IN GASTON COUNTY.

NEAR MOUNT HOLLY.—The terraces along the Catawba river are well developed around Mount Holly and furnish an abundance of clay. About one-quarter mile south of town this clay has been opened up for the manufacture of brick. The deposit lies at the shore line of the terrace and about 35 feet above the river. It is not less than seven feet thick and underlain by sand and gravel. Brick were formerly made from it by Holobaugh, but the yard is no longer running.

The clay is somewhat gritty and slakes slowly but completely. A few mica scales are scattered through it.

The addition of 29% of water gave a very plastic paste, which shrunk 8% in drying and 4.5% in burning, giving a total shrinkage of 12.5%. The average tensile strength of the air-dried briquettes was 131 lbs. per square inch with a maximum tensile strength of 160 lbs. per square inch. Incipient fusion occurs at 1950° F., vitrification at 2100° F., and viscosity at 2250° F. The clay burns to a close red body.

The analysis of this clay yielded as follows:

Analysis of Brick-clay (No. 60), ¼ mile S. of Mt. Holly.

Moisture	1.43
Silica (total)	61.28
Alumina	20.83
Ferric oxide	5.51
Lime	.49
Magnesia	.14

Alkalies	.84
Water (loss on ignition)	8.75
Total	99.27
Clay substance	50.99
Free sand	49.05
Total fluxes	6.98
Specific gravity	2.47

This clay should make a first-class brick that would stand re-pressing. In composition and physical properties it is closely similar to the clay for pottery dug northwest of Lincolnton, but is more sandy in its nature.

CLAY IN GUILFORD COUNTY.

NEAR GREENSBORO.—Both residual and sedimentary clays occur in abundance around the town, and both are utilized by the brick manufacturers. The *Greensboro Brick and Tile Company's yard* is located on the northern edge of the town along the road to Pomona. The clay is a reddish residual clay resulting from the decomposition of gneissic rock, and opened up to a depth of 8 feet. This material is somewhat more sandy in portions of the bank, but all of it is soft. A sample of this clay was found to slake easily to its component grains. It required 28% of water to produce a workable mass, which shrunk 9% in drying and 6% in burning, making a total shrinkage of 15%. This paste was moderately plastic. Air-dried briquettes of the clay had an average tensile strength of 85 lbs. per square inch and a maximum of 96 lbs. per square inch. Incipient fusion occurs at 2050° F., vitrification at 2250° F., and viscosity at 2450° F. The clay burns to a red body.

Its composition is as follows:

Analysis of Greensboro Brick & Tile Co's. Clay (No. 24).

Moisture	1.64
Silica (total)	56.81
Alumina	20.62
Ferric oxide	6.13
Lime	.65
Magnesia	.58
Alkalies	4.47
Water (loss on ignition)	8.60
Total	99.50
Clay substance	58.85
Free sand	40.65
Total fluxes	11.83
Specific gravity	2.44

The high per cent. of alkalies is evidently due to much undecomposed feldspar. A very good building brick is made from this clay. The plant includes a pair of rolls, Freese disintegrator and Freese side-cut auger machine. The brick are dried on a brick floor heated by hot air passing through flues underneath. They have three Morrison kilns in which soft coal is used. Re-pressing has been tried with fair results.

Dean's brickyard is on the southern side of town, and the clay is very similar to that at the Greensboro Brick and Tile Company's yard.

It is a lean, gritty clay, with abundant grains of quartz, feldspar and mica. In water it slakes easily to its component grains.

It absorbed 28% of water in being worked into a paste, which shrunk 10% in drying and 6% in burning, giving a total shrinkage of 16%. The average tensile strength of air-dried briquettes was 66 lbs. per square inch, while the maximum was 77 lbs. per square inch. Incipient fusion occurred at 2100° F., vitrification at 2300° F., and viscosity at 2400° F. The clay burns red. Its composition is shown by the following analysis:

Analysis of Dean's Brick-clay (No. 30) pit, Greensboro.

Moisture	1.90
Silica (total)	59.27
Alumina	22.31
Ferric oxide	6.69
Lime	.25
Magnesia	.13
Alkalies	.90
Water (loss on ignition).....	9.00
Total	100.45
Clay substance	67.20
Free sand	33.25
Fluxes	7.97
Specific gravity	2.46

This clay is used for the manufacture of common brick. It is tempered in a ring pit, molded by hand, dried in the sun, and burned in scove kilns. The product is burned little beyond incipient fusion.

Watson's brickyard uses the same clay and methods as are used at Dean's yard, just described.

Kirkpatrick's brickyard is situated along North Buffalo creek, and the clay is a portion of the deposit to be found more or less continuously along the creek all the way up to Pomona. It is a gray, gritty clay, dense and tough, and slakes slowly to irregular granules.

It required the addition of 30% of water to make a workable paste, which shrunk 11% in drying and 5% in burning, giving a total shrinkage of 16%. Air-dried briquettes of the very plastic paste had an average

tensile strength of 220 lbs. per square inch with a maximum of 232 lbs. per square inch. Incipient fusion occurs at 1900° F., vitrification at 2100° F., and viscosity at 2300° F. It burns to a dense red body, but requires slow heating. The composition is indicated by the following analysis:

Analysis of Kirkpatrick's Brick-clay (No. 31), Greensboro.

Moisture	1.50
Silica (total)	69.70
Alumina	12.87
Ferric oxide	6.13
Lime	2.55
Magnesia	.57
Alkalies	2.79
Water (loss on ignition)	4.08
Total	100.19
Clay substance	35.27
Free sand	64.92
Fluxes	12.04
Specific gravity	2.48

The clay is discharged directly into a steel end-cut auger machine, heated on drying floors, and burned in scove kilns.

CLAY IN HALIFAX COUNTY.

NEAR ROANOKE RAPIDS.—There has been considerable demand for brick at this locality for use in the construction of large cotton mills being erected at this point. The clays used occur along or near the Roanoke river, a few hundred yards south of the cotton mills. The section is in general as follows:

Yellowish sandy clay (sample No. 1).....	2 to 5 ft.
Plastic clay (exposed) (sample No. 2)	6 to 8 ft.

This upper sandy clay is coarse-grained and contains numerous small concretions of sand cemented by limonite. A sample of this upper clay was tested with the following results: The sandy, moderately coarse-grained yellow clay slaked extremely slowly on account of its density. It required 25% of water to produce a workable paste, which to the feel was very lean. This paste shrunk 8% in drying and 5% in burning, giving a total shrinkage of 13%. Air-dried briquettes of the mud had an average tensile strength of 46 lbs. per square inch and a maximum strength of 50 lbs. per square inch. Incipient fusion occurred at 1900° F., vitrification at 2050° F., and viscosity at 2250° F.

At 1900° the clay burned to a reddish, porous body, but at 2050° it

was fairly dense, but deep reddish brown. The little ferruginous concretions fuse to black spots in burning.

The following is the composition of this upper sandy clay.

Analysis of upper sandy Clay (No. 1), Roanoke Rapids.

Moisture	1.63
Silica (total)	67.55
Alumina	13.16
Ferric oxide	8.54
Lime	.17
Magnesia	.28
Alkalies	2.65
Water (loss on ignition)	5.08
Total	99.06
Clay substance	41.98
Free sand	57.08
Total fluxes	11.64
Specific gravity	2.39

The insoluble residue ("free sand") in the above indicates the sandy character of the clay and the reason of its leanness and low tensile strength.

The underlying clay is less sandy and feels far more plastic. It contains a few small mica scales. It slakes moderately fast to grains of small size, and is not a very dense clay. The following description applies to the part of this lower clay (6 to 8 feet thick) exposed and used in the pits at Roanoke Rapids, and here designated the middle clay (sample No. 2):

It required 26.5% of water to make a workable mass, which was highly plastic. This mud shrunk 10% in drying and an additional 5% in burning, giving a total shrinkage of 15%. Air-dried briquettes made from this paste exhibited an average tensile strength of 151 pounds per square inch and a maximum of 168 pounds per square inch. Incipient fusion occurs at 1900° F., vitrification at 2050° F., and viscosity at 2250° F. The clay burns to a red body, much smoother than the preceding sample.

The increased plasticity is very noticeable, and due no doubt in part to the smaller quantity of sand present and perhaps greater fineness of the grains.

The following is the composition of the clay:

Analysis of the middle Brick-clay (No. 2), Roanoke Rapids.

Moisture	2.45
Silica (total)	65.58
Alumina	17.04
Ferric oxide	5.76
Lime	.72
Magnesia	.28

Alkalies	2.30
Water (loss on ignition)	5.58
Total	99.71
Clay substance	56.70
Free sand	31.50
Total fluxes	9.06
Specific gravity	2.59

Another sample (No. 3) of this lower clay, and here designated the under clay, represents its lower portion, extending for several feet below the level of the present floor of the brickyard at Roanoke Rapids, and was collected to show the uniformity of this lower clay. Its general character may be seen from the following description:

To the feel the lower sample of the under clay was about the same in grittiness and fineness of grain as the upper part of this lower clay stratum (No. 2), but the plasticity was seemingly greater. The clay slaked rather readily to irregular granules, requiring 26% of water added to it in order to produce a workable paste, which was very plastic. This paste shrank 10.6% in drying and 5% in burning, making a total shrinkage of 15.6%. The average tensile strength of the air-dried briquettes was 206 lbs. per square inch, and the maximum strength 218 lbs. per square inch.

Incipient fusion occurred at 1900° F., vitrification at 2050° F., and viscosity at 2250° F. The clay burned to a dense red body. Its composition is as follows:

Analysis of the under Brick-clay (No. 3), Roanoke Rapids.

Moisture	2.05
Silica (total)	59.68
Alumina	16.09
Ferric oxide	8.91
Lime	1.35
Magnesia	.14
Alkalies	3.24
Water (loss on ignition)	6.33
Total	97.79
Clay substance	42.28
Free sand	30.82
Total fluxes	13.24
Specific gravity	2.56

A comparison of the three clays sampled from this locality is worth while. The last two, it will be noticed, possess a much greater plasticity than the first, a greater tensile strength, and burn to a denser and harder body at the same temperature than the first one does.

The under bed of this bank is far better suited to the manufacture of good brick than the upper sandy one; and a mixture of the two would be better than using either the upper sandy clay alone or this with sand added. The latter only helps to make the brick more porous in view of its naturally sandy condition.

NEAR WELDON.—Similar clays to those at Roanoke Rapids are dug along the railroad south of the depot; they are used for the manufacture of common building brick.

NEAR HALIFAX also there are extensive beds of clay, but these, like those at Weldon, could not be carefully examined in time for the present report.

CLAY IN HARNETT COUNTY.

NEAR SPOUT SPRINGS.—There are three cuts along the line of the C. F. & Y. V. R. R. between Fayetteville and Spout Springs in which there are exposed considerable quantities of a purplish clay. The first of these is between the 92d and 93d mile post,¹ and just N.W. of McClenahan cut. The clay comes up in a low, dome-shaped mass, showing a maximum thickness of 8 feet above the roadbed. There is very little sand covering, and the clay is remarkably homogeneous in its character. An examination of a sample from this cut showed it to be a fine-grained, tough clay, even grained and with conchoidal fracture. It slakes easily in water to grains. It required 35% of water to give a workable paste that was only slightly plastic but smooth. This paste shrank 10% in drying and 4% in burning, giving a total shrinkage of 14%. Air-dried briquettes made from this paste had an average tensile strength of 27 lbs. per square inch and a maximum of 31 lbs. per square inch.

Incipient fusion occurred at 1950° F., vitrification at 2150° F., and viscosity at 2350° F. The clay burns to a buff at 2000° F., but with more firing turns red. The composition of it is as follows:

Analysis of Brick-clay (No. 16), C. F. & Y. V. R. R., 92-93 mile post.

Molsture	1.42
Silica (total)	64.16
Alumina	21.71
Ferric oxide	1.58
Ferrous oxide	1.08
Lime	.23
Magnesia	.15
Alkalies	.77
Water (loss on ignition)	8.30
Total	99.40

¹ Measuring from Wilmington.

Clay substance	58.55
Free sand	40.90
Total fluxes	3.81
Specific gravity	2.43

The second cut is at the 100-mile post, and the clay shows nine feet of thickness.

Here, again, the clay (No. 17) is very fine-grained and homogeneous, but not quite so gritty as the preceding. It slakes just the same, and required 32% of water to make a workable but rather lean paste, which shrunk 8% in drying and 6% in burning, or a total of 14%. The air-dried briquettes had an average tensile strength of 24 lbs. per square inch and a maximum of 29 lbs. per square inch. Incipient fusion occurred at 1950° F., vitrification at 2150° F., and viscosity at 2350° F. The clay burns to a smooth, red body. Its composition is:

Analysis of Brick clay (No. 17), C. F. & Y. V. R. R., at 100 mile post.

Moisture	1.35
Silica (total)	50.68
Alumina	32.51
Ferric oxide	3.06
Lime	.30
Magnesia	.02
Alkalies	.58
Water (loss on ignition)	11.08
Total	99.58
Clay substance	83.43
Free sand	16.15
Total fluxes	3.96
Specific gravity	2.53

The third cut along the railroad is a half mile southeast of Spout Springs and shows fully 12 feet of this clay; while a fourth exposure of it is in the cut just northwest of Spout Springs station (Plate XII, fig. 2).

The clay exposed in this last mentioned cut possesses the same homogeneous, tough, fine-grained character as those just described. A sample (No. 18) tested from this place slaked quickly and, when mixed with 35% of water, gave a workable, lean, smooth mass that shrunk 9% in drying and 8% in burning, a total shrinkage of 17%. The air-dried briquettes made from this paste had an exceedingly low tensile strength, 19 lbs. per square inch on the average with a maximum of 25 lbs. per square inch. Incipient fusion occurred at 2000° F., vitrification at 2200° F., and viscosity at 2400°. The clay burns to a red-gray dense body. The following is the composition of this clay:



FIG. 1.—BRICKWORKS OF CARTER AND SHEPARD, BETHANIA.
(See page 111.)



FIG. 2.—CLAY DEPOSIT IN RAILWAY CUT, SPOUT SPRINGS, C. F. & Y. V. RAILROAD.

NOV 1966

RECEIVED
JAN 10 1964
U.S. DEPT. OF JUSTICE

Analysis of Clay (No. 18), C. F. & Y. V. R. R., Spout Springs station.

Moisture	1.05
Silica (total)	53.65
Alumina	28.66
Ferric oxide	4.50
Lime	.10
Magnesia	1.35
Alkalies	.29
Water (loss on ignition)	10.79
Total	100.39
Clay substance	73.77
Free sand	26.65
Total fluxes	6.24
Specific gravity	2.41

CLAY IN JACKSON COUNTY.

NEAR SYLVA.—Along the road south of Sylva and three-quarters of a mile from the kaolin washing works is considerable outcropping of gray clay (No. 55) with much quartz. There is also an abundance of mica scales in it. The clay which has been experimented with in the hopes that a ball-clay might be obtained from it by washing, contains too much ferric oxide. Its chief application lies in the manufacture of pressed brick, or to mix with a more plastic clay for vitrified wares, such as sewer-pipe or possibly paving brick.

The clay, which varies from coarse to fine, contains abundant grains of quartz as well as scales of mica. It slakes slowly to irregular grains. The addition of 28% of water gave a tough but stiff mass, which to the feel was gritty and plastic. The shrinkage in drying was 9% and in burning 5%, giving a total shrinkage of 14%. The average tensile strength of the air-dried briquettes was 58 lbs. per square inch, with a maximum of 67 lbs. Incipient fusion occurred at 2100° F., vitrification at 2300° F., and viscosity at 2500° F.

The clay burns red. Its composition is as follows:

Analysis of Brick-clay (No. 55), near Sylva.

Moisture	.45
Silica (total)	66.70
Alumina	19.75
Ferric oxide	3.25
Lime	.45
Magnesia	.16
Alkalies	2.12
Water (loss on ignition).....	6.65
Total	99.53

Clay substance	47.28
Free sand	52.25
Total fluxes	6.08
Specific gravity	2.59

CLAY IN MARTIN COUNTY.

NEAR WILLIAMSTON.—Two samples of residual clay from this locality were submitted to the Geological Survey for testing. The first (No. 66) was a moderately coarse-grained clay which slaked easily to irregular grains. The addition of 40% of water was required to give a workable mass that to the feel was lean and gritty. This mud shrunk 13% in drying and 3% in burning, giving a total shrinkage of 16%. Care had to be exercised in drying to prevent it from cracking. The average tensile strength of the air-dried briquettes was 67 lbs. per square inch, while the maximum was 78 lbs. Incipient fusion occurs at 2000° F., vitrification at 2150° F., and viscosity at 2300° F. The clay burns red at incipient fusion, but above that the color deepens rapidly.

The second sample was similar in appearance to the first one, and, like it, slaked easily to its component grains. The addition of 29% of water gave a workable but lean, sticky mass, which shrunk 10% in drying and 2% in burning, giving a total shrinkage of 12%. The air-dried briquettes had an average tensile strength of 74 lbs. per square inch with a maximum of 100 lbs. Incipient fusion occurred at 2000° F., vitrification at 2150° F., and viscosity at 2200° F.

The clay burns red at 2000° F., but the color becomes much deeper with harder firing.

This clay cracks less than the previous one in drying, for the shrinkage is less.

Both these clays illustrate the lean character and low-binding qualities of some clays, both sedimentary and residual. Their porous nature and avidity for water cause them to soak up large quantities of it, and the consequent expulsion of this water brings about excessive shrinkage and necessitates very slow drying. The only remedy in such cases is the admixture with these lean, porous clays of other clays that are more compact and have better binding qualities.

CLAY IN MECKLENBURG COUNTY.

NEAR CHARLOTTE.—The region in the vicinity of Charlotte is underlain by sedimentary clays in the hollows, and residual clays on the hills. While those in the hollows are largely composed of the wash from the hills, still, on account of the sorting and elimination of coarse particles which follow as a result of the washing, the lowland deposits are smoother and more plastic.

One of the latter class is near *D. K. Cecil's yard* on Trade street at the east edge of the town.

The section of this clay bank shows the following:

Loam (soil)	12-18 inches.
Clay	.8 feet.
Sand	—

The clay is gray, mottled with iron stains, fine-grained, fairly smooth. There is no mica apparent. It slakes quickly.

The addition of 25.8% of water gave a moderately plastic paste with somewhat gritty feel. This paste shrunk 6% in drying and 6% in burning, giving a total shrinkage of 12%. The average tensile strength of air-dried briquettes was 88 lbs. per square inch with a maximum strength of 95 lbs. per square inch.

Incipient fusion occurs at 1850° F., vitrification at 2050° F., and viscosity at 2250° F.

The clay burns to a red, fairly smooth body. Its composition is as follows:

Analysis of D. K. Cecil's Brick-clay (No. 39), Charlotte.

Moisture	1.35
Silica (total)	68.35
Alumina	13.13
Ferric oxide	6.87
Lime	2.10
Magnesia	.32
Alkalies	2.86
Water (loss on ignition)	5.20
Total	100.18
Clay substance	38.73
Free sand	61.45
Total fluxes	12.15
Specific gravity	2.68

Mr. Cecil uses the clay for the manufacture of common brick. The clay is molded in an auger side-cut machine, dried on pallets and burned in scove kilns. The product is usually a hard, dense brick.

At *Houser's yard*, one-quarter mile from Cecil's, there is a similar deposit of sedimentary clay. It contains an abundance of small quartz grains. The bricks are barely burned to incipient fusion. Houser's plant includes a pair of rolls, Brewer side-cut machine, and pallet racks.

The clay from this yard was not tested. It is situated along the same stream as Cecil's deposit.

At *F. M. Sassamon's brickyard*, two miles northwest of Charlotte,

the clay lies in a hollow and covers a number of acres. Its exact thickness is not known, but it is not less than six feet. A sample of this clay was examined and found to be a somewhat coarse-grained, porous clay. It slakes moderately fast to fine aluminous mud and granules. The addition of 35% of water gave a plastic mass, which shrunk 13.3% in drying and 8% in burning, giving a total shrinkage of 21.3%. The drying could not be hurried, as otherwise cracking resulted. The average tensile strength of the air-dried briquettes was 105 lbs. per square inch with a maximum of 125 lbs.

Incipient fusion occurred at 1950° F., vitrification at 2100° F., and viscosity at 2250° F. The clay burns red.

Its composition is as follows:

Analysis of F. M. Sassamon's Brick-clay (No. 42), Charlotte.

Moisture	1.27
Silica (total)	65.95
Alumina	14.67
Ferric oxide	7.61
Lime	2.57
Magnesia	.25
Alkalies	2.55
Water (loss on ignition)	5.52
Total	100.39
Clay substance	43.84
Free sand	56.45
Fluxes	12.98
Specific gravity	2.60

Shuman operates a deposit (No. 41) just north of Charlotte, which is a mixture of sedimentary clay and residuum. It is about 9 feet thick as exposed, and varies from a sandy clay to a fat, tough one.

Most of it is coarse-grained, gritty, and slakes slowly but completely. The clay required the addition of 35% of water to give a workable, though lean mass. Its porous nature permitted rapid drying, and it shrunk 5% in doing so. The shrinkage in burning was 4%, giving a total shrinkage of 9%. Air-dried briquettes had an average tensile strength of 26 lbs. per square inch and a maximum of 28 lbs. Incipient fusion occurred at 2100° F., vitrification at 2200° F., and viscosity at 2300° F. The clay burns to a reddish brick.

The composition of it is as follows:

Analysis of F. W. Shuman's Brick-clay (No. 41), Charlotte.

Moisture	7.10
Silica	59.15
Alumina	18.36

Ferric oxide	6.04
Lime	.20
Magnesia	.34
Alkalies	1.72
Water (loss on ignition)	7.47
Total	100.38
Free sand	39.50
Total fluxes	8.30
Specific gravity	2.44

J. Asbury has a brickyard about one and a half miles north of the town. The section at the clay bank shows four feet of red clay (sample No. 62) and under this six feet of very plastic blue clay. The addition of 25% of water gave a workable paste of good plasticity.

This paste shrank 7% in drying and 5% in burning. The average tensile strength of the air-dried briquettes was 60 lbs. per square inch with a maximum of 72 lbs. per square inch. Incipient fusion occurred at 1900° F., vitrification at 2100° F., and viscosity at 2300° F.

The clay burns red. Its analysis shows the following:

Analysis of J. Asbury's upper red Brick-clay (No. 62), Charlotte.

Moisture	.63
Silica (total)	60.33
Alumina	18.57
Ferric oxide	10.03
Lime	.20
Magnesia	.14
Alkalies	.55
Water (loss on ignition)	7.83
Total	98.28
Clay substance	56.23
Free sand	42.05
Total fluxes	10.92
Specific gravity	2.60

CLAY IN RICHMOND COUNTY.

NEAR ROCKINGHAM.—A red, coarse-grained, sedimentary clay (No. 23) occurs at Roberdell, four miles north of Rockingham. The upper portion of the deposit is somewhat sandy. In practice the bricks seem to shrink considerably in burning and also to crack, but they burn to a deep red color. The deposit is owned by R. L. Steele.

A sample of this clay slaked slowly to grains $\frac{1}{8}$ to $\frac{1}{4}$ in. diameter. It required 26% of water to make a workable paste which shrank 6% in drying and 8% in burning, making a total shrinkage of 14%. It required slow heating to avoid cracking. The average tensile strength

of air-dried briquettes made from this paste was 133 lbs. per square inch with a maximum of 154 lbs. Incipient fusion occurs at 2000° F., vitrification at 2200° F., viscosity at 2400° F. The clay burns to a deep red. It is not fine or smooth enough to be used for pottery. The composition of the clay is as follows:

Analysis of Brick clay (No. 23), 4 miles N. of Rockingham.

Moisture	1.98
Silica (total)	59.59
Alumina	22.07
Ferric oxide	4.27
Lime	.65
Magnesia	.49
Alkalies	2.70
Water (loss on ignition)	7.53
Total	90.28
Clay substance	51.63
Free sand	47.65
Fluxes	8.11
Specific gravity	2.54

CLAY IN ROBESON COUNTY.

NEAR RED SPRINGS.—Five or six brickyards have been in operation at this locality for some years. The flat, wooded region around the town is underlain by abundance of yellowish, coarse-grained, sandy clay of extreme leanness. The abundant sand grains are nearly all pure quartz.

The poor quality of this material is evident on sight, but a sample (No. 19) was tested in order to demonstrate this fact, for there is a tendency among many small manufacturers to use very sandy clay, as it molds easier.

The examination showed it to be a porous, coarse clay, slaking fairly fast in water. It required 17% of water to make a workable mass which was extremely lean. This paste shrank 8.8% in drying and 4% in burning, giving a total shrinkage of 12.8%. Air-dried briquettes had an average tensile strength of 41 lbs. per square inch and a maximum of 51 lbs. Incipient fusion occurred at 2100° F., vitrification at 2250° F., viscosity at 2400° F. At 2100° F. it burns red, but is still porous and weak.

The composition of the clay is as follows:

Analysis of Brick-clay (No. 19), Red Springs.

Moisture	1.09
Silica (total)	78.16
Alumina	8.26
Ferric oxide	4.00
Lime	.40

Magnesia	.22
Alkalies	2.91
Water (loss on ignition)	4.14
Total	90.27
Clay substance	15.22
Free sand	74.05
Total fluxes	7.62
Specific gravity	2.60

The chemical analysis indicates the large percentage of sand in the clay, and the quantity and coarseness of this sand makes the clay too lean. On account of this very high percentage of sand in the clay considerable heat is required to make a hard brick of it.

None of the clay pits at Red Springs are deep, and it is not known whether the clay increases with depth, but if it does the product would be of much better quality by using it.

CLAY IN ROWAN COUNTY.

NEAR SALISBURY.—Half a mile south of the station is an area of swamp land underlain by considerable clay, mostly of a plastic nature.

The section shows 6 feet of clay underlain by sand, and the tract is about an eighth of a mile long. There are occasional iron streaks in the clay, but these are mostly confined to sandy spots. A sample of this clay (No. 48) which was tested showed it to be medium-grained with considerable grittiness. It slaked slowly and required the addition of 28% of water to give a workable mixture which was very plastic. This mass shrunk 8.5% in drying and 5.5% in burning, giving a total shrinkage of 14%. The average tensile strength of air-dried briquettes was 129 lbs. per square inch with a maximum of 144 lbs. Incipient fusion occurs at 1850° F., vitrification at 2050° F., and viscosity at 2250° F.

The clay burns to a red color. Its composition is as follows:

Analysis of Brick-clay (No. 48), south side of Salisbury.

Moisture	1.91
Silica (total)	69.89
Alumina	15.31
Ferric oxide	4.39
Lime	.55
Magnesia	.16
Alkalies	.70
Water (loss on ignition)	6.37
Total	99.28
Clay substance	47.38
Free sand	51.90
Total fluxes	5.80

This clay has been used at D. K. Cecil's brickyard for five years. The clay receives no tempering, but is charged directly into a small auger machine with a three-stream die. The bricks are dried in the sun and burned in scove kilns.

The quality of the brick admits of much improvement, and the quality of the clay warrants it.

CLAY IN SURRY COUNTY.

NEAR ELKIN.—An opening has been made one mile west of town along the railroad and on the property of the Pomona Sewer-pipe Co., and exposes the same yellowish clay as that noted at Wilkesboro. The clay is 8-10 feet deep and underlain by sand and coarse pebbles.

The clay itself (No. 38a) is fine-grained and contains numerous small mica scales and fine grit. It slakes somewhat slowly to its component grains. The addition of 16% of water gave a workable but somewhat lean mud, which shrank 7% in drying and 9% in burning. The average tensile strength of the air-dried briquettes was 69 lbs. per square inch and the maximum was 73 lbs.

Incipient fusion occurred at 1900° F., vitrification at 2100° F., viscosity at 2300° F. The clay burns red and gets very deep red or brown on vitrifying.

The analysis of it yielded the following:

Analysis of Brick-clay (No. 38a), Pomona Co.'s bank, Elkin.

Molsture	.90
Silica (total)	59.48
Alumina	19.24
Ferric oxide	8.26
Lime	.60
Magnesia	1.01
Alkalies	3.76
Water (loss on ignition).....	6.41
Total	99.66
Clay substance	49.21
Free sand	50.35
Total fluxes	13.53
Specific gravity	2.59

Mixed with some more plastic clay, such as that used for sewer-pipe at Pomona, this clay might possibly be used for the manufacture of paving brick.

There are numerous points between Elkin and North Wilkesboro where the cutting of gullies in the terrace has exposed this yellow clay.

The clay used at the brickyards just east and west of Elkin is resid-

ual material of uncertain character and not associated with that down in the valley bottom.

While these yellow clays of the lowlands would doubtless make a good smooth building brick by the soft-mud process, it is doubtful if they would work in an auger machine, and probably refuse to issue from the die without tearing, for there is little bond between the clay particles. In mixing, it also shows slight tendency by itself towards the development of a laminated structure.

CLAY IN UNION COUNTY.

NEAR MONROE.—The lowlands southwest of the depot are underlain by an abundance of blue clay, and though only about 6 feet deep, still it covers a considerable area. As the creek which flows through the lowland is approached the clay becomes more sandy.

A sample of this clay (No. 40) was found to be fairly smooth and slaked slowly but rather completely. It required the addition of 23% of water to produce a workable mass that was very plastic and that shrank 6% in drying and 3% in burning, giving a total shrinkage of 9%. Incipient fusion occurred at 1950° F., vitrification at 2150° F., and viscosity at 2350° F. The clay burns red, but underburning produces a yellowish red.

For a plastic clay the shrinkage is quite low.

The average tensile strength of the air-dried briquettes was 124 lbs. per square inch with a maximum of 148 lbs. per square inch.

It is probable that some of the finer portions of this clay bed could be used for the lower grades of stoneware.

The composition of the clay is as follows, the sample (No. 40) coming from J. T. Shute's clay bank:

Analysis of Brick-clay (No. 40), Shute's clay bank, Monroe.

Moisture	1.65
Silica (total)	76.60
Alumina	9.98
Ferric oxide	4.46
Lime	.30
Magnesia	.27
Alkalies	2.25
Water (loss on ignition)	4.30
Total	99.81
Clay substance	34.28
Free sand	65.55
Total fluxes	7.28

The clay contains a small amount of organic matter and is a good illustration of the combination of low alumina and marked plasticity.

J. T. Shute manufactures common brick from the clay at Monroe. The clay makes a very fair product, but has to be burned carefully.

The bricks are molded in a Brewer auger machine with vertical pug-ging cylinder attached.

CLAY IN WAKE COUNTY.

NEAR RALEIGH.—Much clay of very plastic nature underlies the bottom lands north and east of the city. It has thus far been worked only for building brick, although promising experiments have been made looking towards its utilization for the coarser grades of pottery. A small deposit of considerable plasticity underlies the low ground between Caraleigh Mills and the phosphate mill southeast of town. This deposit is not nearly so extensive, however, as that north of the town in the lowland along the Neuse river.

The clay used at the penitentiary is obtained from the lowland southeast of the city. The upper two feet are a yellowish sandy clay, but under this is a much fatter gray clay possessing considerable plasticity to the feel, and frequently comparatively free from grit in the form of coarse sand grains. A small amount of organic matter is present. It is a tough, fairly compact clay which slakes rather fast to grains and granules. It required the addition of 25% of water to make a workable mass, which shrunk 9.3% in drying and 4% in burning, giving a total shrinkage of 13.3%. Air-dried briquettes made from this mixture had an average tensile strength of 123 lbs. per square inch and a maximum tensile strength of 144 lbs. per square inch. Incipient fusion occurred at 2000° F., vitrification at 2150° F., and viscosity at 2300° F. The clay burns to a red, which increases in depth of color when the clay is burned to vitrification. The composition of this clay is shown by the following:

Analysis of Brick-clay (No. 23), Penitentiary Yard, Raleigh.

Molsture	1.60
Silica (total)	70.03
Alumina	15.64
Ferric oxide	2.88
Lime	.80
Magnesia	.57
Alkalies	1.47
Water (loss on ignition)	6.37
Total	99.36
Free sand	54.55
Clay substance	44.81
Total fluxes	5.72
Specific gravity	2.54

The low percentage of total fluxes accounts partly for the fusion point being 2300°.

It is probable that some of the smoother portions of this clay deposit would work very well for common stoneware.

The clay underlying A. H. Green's land on the north side of the river is less gritty.

The clay-working industry around Raleigh is confined to the manufacture of common brick. These are made by the Caraleigh Mills Company and the North Carolina State Penitentiary. Both used hand-molds and dry the bricks in the sun and burn them in up-draft, open-top kilns. Considering the method of molding, the clay makes a very good red building brick. Steam-power machinery would no doubt greatly increase the value of the product. Re-pressing has been tried with considerable success, and brick thus treated were used in the governor's mansion at Raleigh.

CLAY IN WAYNE COUNTY.

NEAR GOLDSBORO.—There are extensive beds of sedimentary clay underlying the lowlands southeast of the town. At the *Goldsboro Brick and Tile Company*, or Grant's yard, one mile southwest of Goldsboro, quite a large surface has been worked over in obtaining its clay, in order to use the clay at the surface, which is far more sandy but of good plasticity. The exact depth of the clay is not known.

A track runs along the central portion of the excavation, and the clay is dug by means of scrapers and brought to cars on the track. These cars are hauled to the foot of an incline and drawn up by cable to the second floor of the works, where the clay is discharged. It passes first through a pair of rolls and then to the pugmill, from which it is discharged into a Kell's auger machine. The brick are side-cut, and the cutting table is operated by hand power. Ten brick are cut at a time and discharged from the cutting table on to a pallet. The bricks are carried directly to the drying chambers. These consist of a series of cupboards, across which runs a series of parallel steam-pipes, which serve as a shelving. The pallets are shoved endwise into each chamber. In the practice of this method a considerable per cent. of the brick may be lost when, in pushing the pallet into the chamber, the "off-bearer" pushes against the end brick instead of the pallet and crushes the former all out of shape. The drying requires three days when heat is applied during the daytime only. The yard is also equipped with pallet racks.

Burning is done in up-draft kilns with a capacity of about 200,000 each. The bricks are burned to a light red.

The upper part of the clay consists of tough, light-blue plastic clay

with much intermixed sand. The use of the rolls is supposed to break up these lighter-colored lumps of clay, but it does not always do so entirely, as can be seen from an inspection of the burned brick, the lighter-colored lumps of the clay occasionally showing within. A wet pan would probably give better results. The mixture of the sandy and tough clay gives the best results and makes a good brick.

A sample of this clay was tested. It was a coarse to fine-grained clay (No. 7) that slaked irregularly. The addition of 33 per cent. of water gave a fairly plastic and somewhat tough mass, which shrunk 8% in drying and 6% in burning, giving a total shrinkage of 14%. The air-dried briquettes had an average tensile strength of 65 lbs. per square inch and a maximum tensile strength of 74 lbs. per square inch. Incipient fusion occurs at 1900° F., vitrification at 2100° F., and viscosity at 2300° F.

This kind of clay should be thoroughly mixed, and when so treated it burns to a uniform attractive red, but if the clay be not well mixed the lumps of tougher clay are plainly seen if the temperature is raised rapidly so that the iron in them does not get a chance to become thoroughly oxidized. The composition of this clay mixture is as follows:

Analysis of Grant's Brick-clay (No. 7), Goldsboro.

Molsture	1.58
Silica (total)	66.05
Alumina	17.81
Ferric oxide	6.69
Lime	.30
Magnesia	.25
Alkalies	1.04
Water (loss on ignition)	6.32
Total	100.04
Clay substance	51.47
Total fluxes	7.76
Free sand	48.05
Specific gravity	2.53

Near the factory of the Goldsboro Brick and Tile Company is a considerable quantity of tough clay which is called "fire-clay," but which is not a true fire-clay as that term is generally used. This clay simply requires a little more heat in burning the brick than the clay usually employed.

A sample of this "fire-clay" showed it to be a tough, plastic, fine-grained clay with scattered scales of mica. It slakes moderately fast to a mixture of fine powder and small angular quartz grains. The addition of 25% of water gave a plastic, workable paste that shrunk 8.5% in

drying and an additional 5% in burning, giving a total shrinkage of 13.5%. The air-dried briquettes made from this paste had an average tensile strength of 107 lbs. per square inch and a maximum of 125 lbs. per square inch. Incipient fusion occurs at 1950° F., vitrification at 2150° F., and viscosity at 2300° F. The clay burns to a deep red, tough, dense body, and might be worked for stoneware.

The following analysis shows its composition:

Analysis of Grant's "Fire-clay" (No. 9), Goldsboro.

Moisture	1.12
Silica (total)	65.95
Alumina	13.51
Ferric oxide	4.04
Lime	.35
Magnesia	.36
Alkalies	2.82
Water (loss on ignition)	11.58
Total	100.33
Clay substance	49.63
Total fluxes	8.17
Free sand	50.70
Specific gravity	2.55

On account of the high percentage of combined water the clay had to be heated very slowly to prevent cracking.

H. Weil & Bros.' yard and clay bank are about a mile and a half southwest of Goldsboro. Their clay deposit, which is an extension of that of the Goldsboro Brick & Tile Co., contains a considerable quantity of plastic clay. This is 8 feet thick in places, and towards the surface becomes mixed with sand. The clay is molded by hand and pugged in a vertical mill operated by horse-power. The water-smoking and burning is done in the rather short time of five days.

A sample of the plastic clay (No. 8) tested showed it to be moderately fine with considerable grit and mica scales. The clay is somewhat porous but tough, and slakes slowly to irregular grains. The addition of 25% of water gave a workable mixture of fair plasticity. It shrunk 8.3% in drying and 3% in burning, giving a total shrinkage of 11.3%. The air-dried briquettes made from the worked-up paste had an average tensile strength of 85 lbs. per square inch and a maximum strength of 102 lbs. per square inch. Incipient fusion occurs at 1900° F., vitrification at 2100° F., and viscosity at 2300° F.

The clay burns to a red color. Underburning and imperfect oxidation make the brick grayish-red or brown, and porous.

The composition of the clay is as follows:

Analysis of Weil's Brick-clay (No. 8), Goldsboro.

Moisture	1.85
Silica (total)	67.90
Alumina	18.74
Ferric oxide	3.16
Lime	.40
Magnesia	.45
Alkalies	1.85
Water (loss on ignition)	6.03
Total	100.38
Clay substance	46.23
Total fluxes	5.86
Free sand	54.15
Specific gravity	2.57

CLAY IN WILKES COUNTY.

NEAR WILKESBORO.—The valley of the Yadkin river at this locality is nearly three-quarters of a mile wide, and its broad, flat bottom is underlain by an abundance of clay.

At *D. Smoak's yard*, on the south side of the river just west of the iron bridge, the clay is said to be 13 feet thick and to be underlain by gravel and sand. As the river is approached, the surface sand increases in depth. The clay is claimed to improve greatly with the depth, so a sample (No. 37) was taken from the bottom of the deposit and one (No. 36) representing the average material now used.

The latter (No. 36) is a fine-grained, yellowish clay with numerous very small mica scales. It slakes quite rapidly and completely to fine grains. The addition of 25% of water gave a workable but lean paste. This paste shrunk 5% in drying and 10% in burning, giving a total shrinkage of 15%. The average tensile strength of the air-dried briquettes was 74 lbs. per square inch with a maximum of 76 lbs. per square inch.

Incipient fusion occurs at 1900° F., vitrification at 2100° F., and viscosity at 2300° F.

At 2100° the clay burns to a good red, but above this temperature it darkens rapidly.

The composition of this clay is as follows:

Analysis of Smoak's Brick-clay (No. 36), Wilkesboro.

Moisture	1.03
Silica (total)	53.75
Alumina	24.91
Ferric oxide	7.99
Lime	.70
Magnesia	1.12

Alkalies	2.94
Water (loss on ignition)	7.60
Total	100.04
Clay substance	54.04
Total fluxes	12.75
Free sand	46.00
Specific gravity	2.63

The bottom clay (No. 37) at Smoak's brickyard is also a fine-grained, yellowish-brown clay with abundant fine grit and small mica scales. It slakes rather quickly and completely to its component grains. The clay required 24% of water to make a workable paste, which was somewhat lean.

This paste shrunk 6% in drying and 9% in burning, giving a total shrinkage of 15%. The average tensile strength of the air-dried briquettes was 71 lbs. per square inch with a maximum of 84 lbs.

Incipient fusion occurred at 1900° F., vitrification at 2100° F., and viscosity at 2300° F.

The clay burns to a bright red at 1900° F., but this rapidly darkens as the temperature is raised.

The physical characters of this clay are therefore closely similar to that composing upper portions of the deposit.

The composition of this lower clay is as follows:

Analysis of Smoak's bottom Brick-clay (No. 37), Wilkesboro.

Moisture	2.10
Silica (total)	52.25
Alumina	20.66
Ferric oxide	11.14
Lime	.60
Magnesia	1.08
Alkalies	4.62
Water (loss on ignition)	7.45
Total	99.90
Clay substance	57.45
Total fluxes	17.44
Free sand	42.45
Specific gravity	2.44

In fluxes this bottom clay runs several per cent. higher than the top and contains less alumina.

This clay and the preceding one described underlie the same terrace as does the pottery clay on the Calvin Cowles land, the two being not more than half a mile apart (see p. 79).

Mr. Smoak uses the yellowish clay for the manufacture of common brick. It is molded by hand, dried in the sun and burned in up-draft, permanent side-wall kilns. The clay makes a good brick, and also yields promising results with re-pressing. Some of the re-pressed brick are to be seen in the bank building at North Wilkesboro.

CLAY IN WILSON COUNTY.

NEAR WILSON.—Sedimentary clay occurs in considerable quantity on the east and northeastern edge of the town and is extensively worked. The A. C. L. R. R. passes close to the deposits. At S. Lucas's yard, northeast of the town along the railroad, the section is as follows:

Sandy soil	1 ft.
Sand, clayey in spots.....	2 ft.
Sandy clay, red	3 ft.
Blue clay	3 ft. +

The sandy soil is stripped and a mixture of the remaining portion of the section used. Two openings have been made which show similar sections, but the clay in the southern one is red while that in the northern one is blue. Little iron concretions are not uncommon in the upper portion of the bed, and these in burning produce fused spots.

The red clay (No. 4) is the more sandy of the two. It is a gritty clay, porous and slakes very quickly. The addition of 32% of water gave a lean mass, which shrunk 10% in drying and 5% in burning, giving a total shrinkage of 15%. The average tensile strength of air-dried briquettes made from this paste was 84 lbs. per square inch and the maximum 98 lbs. Incipient fusion occurred at 1800° F., vitrification at 1950° F., and viscosity at 2100° F. The clay burns to a red but not very dense body. With hard firing it becomes converted into a black, impervious body in which the individual quartz grains stand out with great distinctness.

The composition of the clay is as follows:

Analysis of red Brick-clay (No. 4), Lucas' Yard, N. E. of Wilson.

Moisture	2.31
Silica (total)	62.90
Alumina	13.56
Ferric oxide	11.52
Ferrous oxide	0.33
Lime	.10
Magnesia	.20
Alkalies	2.07
Water (loss on ignition)	6.03
Total	99.20

Clay substance	55.95
Total fluxes	14.31
Free sand	43.25
Specific gravity	2.62

The insoluble residue is probably mostly quartz, and the high percentage of ferric iron gives the clay its red color.

The blue clay is also gritty to the feel, somewhat finer grained than the red, and slakes slowly to scaly grains in water. Like the red, it shows no mica scales. It required 30% of water to produce a workable paste. This was quite plastic and shrunk 8% in drying and 5.5% in burning, giving a total shrinkage of 13.5%. Briquettes of this air-dried paste had an average tensile strength per square inch of 107 lbs. and a maximum of 129 lbs., much stronger, it will be seen, than the red. Inoipient fusion occurs at 1900° F., vitrification at 2050° F., and viscosity at 2200° F. The clay burns to a red.

Its composition is as follows:

Analysis of Lucas' blue Brick-clay (No. 5), N. E. of Wilson.

Molsture	1.70
Silica (total)	68.90
Alumina	14.36
Ferric oxide	6.04
Lime	.03
Magnesia	.31
Alkalies	2.80
Water (loss on ignition)	5.83
Total	90.47
Clay substance	48.72
Total fluxes	8.08
Free sand	51.75
Specific gravity	2.45

Mr. Lucas has a second clay bank east of the town, from which he also uses the clay for making common brick. The clay in appearance and feel, chemical composition and physical properties, is closely like that described above as used at the other yard, but the claim is made that it not only shrinks less in burning but even swells sometimes. For this reason the clay was examined. The only apparent difference from that at the other yard, northeast of the town, lies in its slightly higher fusibility, and, consequently, with only the same amount of firing as that given to the other clay, this one would shrink less. It is a gritty clay which slakes slowly and requires the addition of 33% of water to give a workable paste that to the feel was very plastic. This paste shrunk 11% in drying and 4% in burning, giving a total shrinkage of 15%.

The air-dried briquettes made from this paste had an average tensile strength of 138 lbs. per square inch and a maximum of 155 lbs. per square inch.

Incipient fusion occurred at 1950° F., vitrification at 2100° F., and viscosity at 2250° F. The color of the burned clay was red. Its composition, as shown by the following analysis, corresponds closely with that of the preceding sample.

Analysis of Lucas' Brick clay (No. 6), E of Wilson.

Moisture	1.68
Silica (total)	68.28
Alumina	13.59
Ferric oxide	5.06
Lime	.15
Magnesia	.47
Alkalies	2.82
Water (loss on ignition)	6.00
Total	98.65
Clay substance	43.60
Total fluxes	7.69
Free sand	53.55
Specific gravity	2.52

Other clays of the same nature are exposed for some distance along the railroad track north and south of Wilson. A number of buff brick have been made from a deposit lying south of the town.

COMPARISON OF CLAYS FROM WILSON AND WAYNE COUNTIES.

The clays at Wilson and Goldsboro are, as has been previously stated, of sedimentary nature and somewhat similar in character.

Experiments and actual practice point to the fact that very different results can be obtained from these clays by the use of different methods. Hand-molding, improper tempering and hurried burning give a poor, porous, badly-colored brick. Steam power machines give a much smoother brick. Auger machines were tried by some and given up in disgust, but the machines used had the shortest possible pugmill and the clay received no other tempering. When rolls are used they seldom do more than flatten out the tough lumps of clay. In a cheap auger machine the die is often improperly constructed, and laminations of the worst kind may be produced in the brick. If the brick is not thoroughly burned, these laminations will result in the shelling off of fragments from the brick.

CHAPTER X.

MANUFACTURE OF PAVING BRICK.

Few paving brick are manufactured in North Carolina, but as some of the clays give indications of applicability for this purpose, it may be well to say a few words regarding the manufacture of brick for paving purposes. General practice has shown that shales are par excellence the material for making paving brick, for on account of their fusible impurities they burn to such a dense body. Shales, however, are not always obtainable, and then other clays have to be used. It is highly probable that mixtures of clays can be used in North Carolina for this purpose. A mixture of the top and bottom clay from Emma, in Buncombe County, was tried and burned to a dense, hard body. The clays at Elkin and Wilkesboro also burn to a dense, impervious mass, but they lack somewhat in plasticity and would have to be mixed with a more plastic clay.

REQUISITE CHARACTER OF CLAY.

Clays used for making paving brick should have sufficient fluxing impurities to enable them to burn to a dense, impervious body at a moderate temperature.

Wheeler¹ gives the following average composition of a paving brick clay deduced from fifty reliable sources.

Average composition of paving-brick clay.

	Minimum per cent.	Maximum per cent.	Average.
Moisture	0.5	3.0	1.5
Silica	49.0	75.0	56.0
Alumina	11.0	25.0	22.5
Ferric oxide	2.0	9.0	6.7
Lime	0.2	3.5	1.2
Magnesia	0.1	3.0	1.4
Alkalies	1.0	5.5	3.7
Water (loss on ignition).....	3.0	13.0	7.0
Total fluxes	—	—	13.0

Chemical composition alone does not determine the use of a clay for paving brick. It should be quite plastic to permit molding without

¹ *Vitrified Paving Brick.*

tearing in a stiff-mud auger machine, but not excessively plastic, otherwise laminations result.

From a commercial standpoint, it is of course desirable that the shrinkage in drying and burning should be moderate, and that the clay will permit drying in 24 to 36 hours. In fact, the lengthening of any of the stages of the process of manufacture increases the cost.

An important point is that the greater the difference in temperature between incipient fusion and viscosity the safer it is to thoroughly vitrify the brick. The difference in temperature between incipient fusion and viscosity should not be less than 250° F. and preferably 400° F.¹

The color of a paving brick is *no* indication of its quality.

MANUFACTURE OF PAVING BRICK.

If shale is used it is first crushed in a dry pan and then screened.

The screened clay is mixed with water in a pugmill of the type described under building brick.

From the pugmill the clay passes into the stiff-mud machine, which has been already mentioned (p. 97). Few paving brick manufacturers now use anything except the auger machine. The brick may be either end-cut or side-cut according to the clay. Re-pressing the green brick is also commonly done, but the manner of re-pressing may have a marked effect on the wearing power of the brick.

Experiments by Prof. E. Orton, Jr.,² have shown that end-cut re-pressed paving brick are the toughest.

The brick are generally piled on cars and run into tunnels to dry. These tunnels are heated by steam-pipes, or coal or oil fires.

The cars are run in at one end and always discharged from the other.

Paving brick should be burned in down-draft kilns, as they give far better results than the up-draft ones. The kiln may be either circular or rectangular. Circular kilns have small capacity and are cheap to erect, but little used outside of Ohio. Their capacity is about 25,000 brick.

Rectangular kilns of 150,000 to 200,000 capacity are the most used. There are several types, but their principle is the same. The flames and heat enter the kiln at the bottom and pass upwards in pockets set against the wall of the kiln and running half-way or three-quarters to the roof. The heat escapes from the top of the pockets or bags into the kiln, passes downward through the brick and out through the openings in the floor to the flues leading to the chimney.

¹ Olchewsky, in *Post. Chem. Tech. Analyse*, 1890, and Wheeler, *Vitrified Paving Brick*, 1885.

² *Clay Worker*, Feb. and March, 1897.

The difference between the various makes of kiln consists in the size and shape of the fireplaces, arrangement of flues, slight differences in bag walls, number of stacks, etc. Among the various types may be mentioned those of Eudaly, Graves, etc. Figure 2 of Plate X (p. 101) shows a Eudaly down-draft kiln.

As paving brick soften somewhat in burning to vitrification, it is necessary not to make too many courses, otherwise the lower ones are liable to be crushed out of shape. The water-smoking period varies according to the clay, but 3-4 days is the average, and the burning takes from 4 to 7 days longer. The kiln should be cooled very slowly in order to anneal the brick and give it that great degree of toughness characteristic of all good pavers.

Great care should be taken to avoid any cold air entering the kiln and checking the pavers.

At several localities continuous kilns are used in the burning of paving brick, but while they work fairly well, they are not yet a thoroughly established success.

CHEMICAL ANALYSES OF NORTH CAROLINA CLAYS.

Field No. used in this report.	Chemical Laboratory No.	Page in Report where Described.	LOCALITY.	Mixture.	Silica (Total).	Alumina.	Ferrie Oxide.	lime.	Magnesia.	Alkalies.	Water Loss on Ignition.	Miscellaneous.	Total.	Clay substance.	Total Fluxes.	Free Sand.	Remarks.
				No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13	No. 14
11	502	102	BLADEN COUNTY.														
			Upper brick-clay, middle of bluff. Prospect Hall	4.50	56.13	17.80	5.85	.10	.79	2.45	11.60*	Sulphur.	98.22		7.29	27.18	Not worked.
10	502	103	Middle brick-clay; bluff at Prospect Hall	2.80	63.30	15.87	5.48	.27	.21	2.40	8.25*	1.78	100.36	43.06	10.14	57.30	Not worked.
12	559	103	Bottom brick-clay, bluff at Prospect Hall	4.26	53.65	20.86	5.11	.30	.64	2.13	9.84*	Sulphur.	100.07	85.03	9.36	15.05	Not worked.
59	505	104	BUNCOMBE COUNTY.														
58	578	105	Upper clay, Penniman's, Emma	1.15	66.27	19.95	3.16	.20	.32	1.85	6.17	Ferrous oxide.	99.74	49.24	6.20	50.40	Brick.
65	572	107	Lower clay, Penniman's, Emma	.80	70.66	17.21	3.44	.10	.07	2.45	5.00	.67	99.73	41.71	7.16		
			Clay, Fletcher	1.10	73.08	13.73	3.47	.30	.17	1.43	4.65		99.99	46.18	5.43		
51	512	75	BURKE COUNTY.														
52	514	107	Pottery clay, McDowell's, Morganton	1.88	60.58	14.03	6.41	.40	.27	1.65	5.73		99.75	45.47	8.73	54.28	Not worked.
			Brick-clay, McDowell's, Morganton	1.80	61.03	13.88	6.50	1.00	1.16	.80	4.78		100.06	39.90	9.58	60.06	
50	557	76	CATAWBA COUNTY.														
			Pottery clay, northwest of Blackburn	2.08	50.17	23.77	2.88	.05	.22	1.04	14.03*		99.24	73.19	4.19	23.05	Stoneware.
43	516	81	CLEVELAND COUNTY.														
			Eskridge pit, Grover	.76	68.23	13.83	2.60	.70	.13	2.29	6.47	Titanic acid.	100.38	46.99	5.72	53.30	Fire-clay.
44	547	82	Powhatan Clay Manufacturing Co's. pit, Grover	1.29	53.07	29.54	1.27	.15	.14	.87	9.98	1.00	98.54	61.99	4.71	36.55	White pressed brick.
45	571	83	Powhatan Clay Manufacturing Co's. pit, ½ mile E. of Grover	.95	64.13	22.35	1.95	.10	.22	.99	5.98		98.48	46.88	5.07	51.60	
46	544	108	Under clay, Cleveland Brick Co., S. of Grover	1.18	61.75	23.90	3.34	.27	.25	1.81	7.75	Ferrous oxide.	99.65	60.62	5.67	39.16	Red brick.
47	532	109	Upper clay, Cleveland Brick Co., S. of Grover	.63	65.45	20.02	4.18	.25	.29	1.51	6.58	.50	98.91	47.06	6.23	51.45	Red brick.
14	563	110	CUMBERLAND COUNTY.														
			E. A. Poe's pit, ½ mile S. of Fayetteville; average clay	2.48	64.93	17.08	5.57	.43	.59	3.85	6.58		101.51	53.13	10.44	45.90	Bricks.
15	560	111	E. A. Poe's pit, ½ mile S. of Fayetteville; "tough" clay	3.23	58.17	20.10	7.43	.60	.77	2.60	7.34		100.24	48.09	11.40	53.15	Not worked.

	No. 1	No. 2	No. 3	No. 4	No. 5 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13	No. 14
FORSTH COUNTY.													
33	523	112	Lower clay, Bethania.....	.90	64.39	19.11	5.39	.80	.22				Brick and Tile.
33	504	112	Upper clay, ""	1.85	55.81	20.06	11.75	.83	.16				Brick and Tile.
GASTON COUNTY.													
60	535	113	Mount Holly, ¼ mile south	1.43	61.28	20.83	5.51	.49	.14				Not worked.
GUILFORD COUNTY.													
30	503	115	Dean's clay Greensboro	1.90	59.27	22.31	6.69	.25	.13				Drick.
24	546	114	Greensboro Brick and Tile Co.'s clay, Greensboro	1.64	56.81	20.62	6.13	.63	.58				Drick.
31	542	116	Kirkpatrick's clay pit, Greensboro	1.50	69.70	12.87	6.13	2.55	.37				Drick.
25	550	84	Fire-clay, first pit, Pomona Terracotta Co.....	.98	70.45	17.34	3.16	.25	.22				Ferrous oxide. .58
26	556	89	Under pipe-clay, first pit, Pomona Terracotta Co.....	1.53	53.73	23.94	3.71	.05	.09				Sewer-pipe.
27	515	89	Upper pipe-clay, first pit, Pomona Terracotta Co.....	2.05	54.28	23.27	8.45	.45	.18				Sewer-pipe.
28	565	90	Pipe-clay, second pit, Pomona Terracotta Co.....	2.20	70.75	13.87	5.01	.82	.29				Sewer-pipe.
25a	585	85	Under fire-clay, Pomona Terracotta Co., Pomona, N. C.	1.17	70.15	15.51	3.24	.83	.07				Fire-brick.
29	597	85	Woodruffe's fire-clay, 1 m. N. of Pomona	1.43	71.60	13.27	3.33	.17	.21				Fire-brick.
HALIFAX COUNTY.													
1	513	117	Upper sandy clay, Roanoke Rapids	1.63	67.55	13.16	8.54	.17	.28				Brick.
2	541	117	Middle clay, "	2.45	65.58	17.04	5.73	.72	.23				Brick.
3	554	118	Under clay, "	2.06	59.68	16.09	8.91	1.35	.14				Brick.
HARNETT COUNTY.													
16	506	119	Clay, C. F. & Y. V. R. R., 92-93 mile post, S. E. of Spout Springs.....	1.42	64.16	21.71	1.53	.23	.15				Not worked.
17	566	120	Clay, C. F. & Y. V. R. R., 100 mile post, S. E. of Spout Springs.....	1.35	50.68	35.51	3.06	.30	.02				Not worked.
18	520	121	Clay, W. of Spout Springs station.....	1.05	53.65	23.66	4.50	.10	1.35				Not worked.
JACKSON COUNTY.													
53	527	61	Washed kaolin, Harris Clay Co., near Webster	.35	45.70	40.61	1.39	.45	.09				Whiteware.
54	526	62	Crude kaolin, Springer mine, near Web ster.. ..	.25	62.40	23.51	1.14	.57	.01				Whiteware.
56	541	62	Washed kaolin, Springer mine, near Webster.....	2.05	45.78	33.46	.28	.50	.04				Whiteware.
57	558	59	Washed kaolin, N. C. Mining & Mfg. Co., near Sylva.....	3.07	44.08	36.26	1.86	.43	.20				Whiteware.
55	525	121	Brick-clay, ½ mile S. of Sylva	.45	66.70	19.75	3.25	.48	.16				Not worked.

Field No. used in this report.	Chemical Laboratory No.	Page in Report where Described.	LOCALITY.	Molecule.	Silica (Total).	Alumina.	Ferric Oxide.	Lime.	Magnesia.	Alkalies.	Water Loss on Ignition.	Miscellaneous.	Total.	Clay substance.	Total Fluxes.	Free Sand.	Remarks.
				No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13	No. 14
			LINCOLN COUNTY.														
61	543	77	Pottery clay, T. Rhodes' place, 2 miles N. W. of Lincolnton.....	2.10	57.20	24.82	3.25	.73	.13	.03	8.25	1.42	98.83	62.27	6.46	36.57	Stoneware.
49	524	78	Pottery clay, T. Rhodes' place, 2½ miles N. W. of Lincolnton.....	.69	57.08	29.11	4.64	.20	.16	1.42	8.52		98.82	62.76	6.42	35.96	Stoneware.
69	577	63	Crude kaolin, near West's mill; Brin- del's land.....		53.10	33.06	1.18	.38	.08	.83	11.32		99.95	83.39	2.47	16.56	
			MACON COUNTY.														
			MECKLENBURG COUNTY.														
39	553	123	D. K. Cecil's yard, Charlotte.....	1.35	68.35	13.13	6.87	2.10	.32	2.82	5.20		100.18	38.73	12.15	61.45	Brick.
41	574	124	F. W. Shuman's yard, Charlotte.....	7.10	59.15	18.36	6.04	.20	.34	1.72	7.47		100.38	43.84	8.30	39.50	Brick.
42	551	124	F. M. Sussamon's yard, Charlotte.....	1.27	65.95	14.67	7.61	2.57	.25	2.55	5.52		100.39	43.84	12.98	56.45	Brick.
62	528	125	Upper clay, J. Asbury's yard, Charlotte.	.63	60.33	15.57	10.03	.20	.14	.55	7.83		98.28	56.53	10.92	42.05	Brick.
			MONTGOMERY COUNTY.														
64	579	65	Dark kaolin, washed, 4 miles W. of Troy.	.53	86.03	6.46	2.14	.17	.04	1.00	2.90		99.27	30.83	3.35	78.54	
68a	576	65	White " " " " " " " " " " " "	.75	63.10	23.33	2.37	.15	.09	1.90	7.65		99.94	58.92	5.11	41.08	
48	547	127	D. K. Cecil's pit, Salisbury.....	1.91	69.89	15.31	4.39	.55	.16	.70	6.37		99.28	47.38	5.80	51.90	Brick.
			RICHMOND COUNTY.														
20	536	67	Kaolin, near Bosticks mills.....	.08	70.63	21.81	1.49	.20	.29	1.45	4.04		99.99	47.14	3.43	52.86	Not worked.
21	567	67	" " " " " " " " " " " "	.17	68.15	19.99	1.86	.13	.16	2.85	4.70		98.01	49.30	5.00	50.70	Not worked.
22	568	67	" " " " " " " " " " " "	..	73.70	16.03	1.57	.38	.47	1.90	4.33		98.38	36.05	4.32	62.33	Not worked.
23	564	126	R. L. Steele's pit, 4 miles N. of Rock- ham.....	1.98	59.50	22.07	4.27	.65	.49	2.70	7.53		99.28	51.63	8.11	47.05	Brick.
			ROBESON COUNTY.														
19	552	126	Clay, Red Springs	1.09	78.16	8.26	4.09	.40	.22	2.91	4.14		99.27	15.22	7.62	74.05	Brick
			SURRY COUNTY.														
		138	Pomona Sewer-pipe Co.'s pit, 1 mile W. of Elkin	.90	59.48	10.24	8.26	.60	1.01	3.76	6.41		99.06	49.21	13.53	50.35	Not worked.

		No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	No. 12	No. 13	No. 14
40	500	129	UNION COUNTY.												
			1.65	76.60	9.98	4.46	.80	.27	2.25	4.30	99.81	34.26	7.38	65.85	Brick.
23		130	WAKE COUNTY.												
			1.60	70.03	15.64	2.88	.80	.57	1.47	6.37	99.38	44.81	5.72	54.85	Brick.
7	501	132	WAYNE COUNTY.												
8	503	134	1.53	69.05	17.81	6.69	.80	.25	1.04	6.32	100.01	51.47	7.78	48.05	Brick.
9	513	133	1.85	67.90	18.74	3.16	.40	.45	1.85	6.08	101.38	46.23	5.93	54.15	Brick.
	518	135	1.12	65.95	13.51	4.64	.86	.36	2.82	11.56	100.33	49.63	8.17	50.70	Not worked.
34	511	78	WILKES COUNTY.												
85	508	79	1.28	54.38	27.27	5.48	.45	.41	.68	9.78	99.73	75.73	7.02	24.00	Stoneware.
86	521	134	2.30	64.24	24.97	4.83	.57	.70	2.52	9.40	99.43	67.08	8.02	32.35	Not worked.
37	510	135	1.03	53.75	24.91	7.99	.70	.12	2.94	7.60	100.04	34.04	12.75	46.00	Brick.
			2.10	52.25	20.66	11.14	.60	.08	4.62	7.45	99.90	57.45	17.44	42.45	Brick.
4	549	136	WILSON COUNTY.												
5	555	137	2.31	62.66	13.56	11.52	10	.29	2.07	6.03	99.20	55.90	14.31	43.25	Brick.
6	519	138	1.70	68.90	14.39	6.04	.03	.31	2.30	5.83	99.47	46.72	8.68	51.75	Brick.
			1.68	68.28	13.59	5.66	15	.47	1.41	6.00	97.24	43.69	7.69	53.55	Brick.

Ferrous oxide.

.33

TABLE OF PHYSICAL PROPERTIES OF CLAYS.

Field Number.	Page in Report where described.	LOCALITY.	Per cent. water added to give workable paste.	Plasticity.	PERCENTAGE.			Average tensile strength, lbs. per sq. in.	Character of Shaking.	Texture of Clay.	DEGREES FAHR.			Total Fluxes.	Color when burned.	Specific Gravity.
					Air Shrinkage.	Fire Shrinkage.	Total Shrinkage.				Incipient Fusion.	Viscosity.	Viscosity.			
BLADEN COUNTY.																
10	103	Middle black clay, middle of bluff, Prospect Hall	22	Lean.	5	8	13	46	Slow.	Coarse.	2000	2150	2200	10.14	Deep red.	2.43
11	102	Upper black clay, bluff at Prospect Hall.	38	Lean.	6	8	14	64	Slow.	Same to fine.	1900	2100	2200	7.29	Deep red.	2.34
12	103	Bottom " "	40	Lean.	12	6	17	59	Slow.	Medium.	1900	2100	2200	9.36	Deep red.	2.30
HUNCOMBE COUNTY.																
104	104	Upper clay, Penniman's, Emma	20	Moderate.	9	4	13	63	Fast.	Coarse.	2000	2200	2400	6.20	Red.	2.50
58	105	Lower " "	28	Moderate.	7	4	11	53	Fast.	Coarse.	2050	2250	2450	6.20	Gray-buff.	2.48
65	107	Clay, Fletcher	25	Slight.	4	7	11	37	Slow.	Fine.	2000	2200	2400	5.42		2.41
BURKE COUNTY.																
51	75	Pottery clay, McDowell's, Morganton	36	Slight.	9.6	4.5	14.1	60	Fast.	Fine.	1950	2100	2250	8.73	Red.	2.59
52	107	Brick-clay, " "	22	Slight.	6	5	11	56	Fast.	Coarse.	1850	2100	2250	9.56	Red.	2.61
CATAWBA COUNTY.																
50	76	Pottery clay, northwest of Blackburn	30	Very good.	12	7	19.0	148	Slow.	Fine.	1950	2100	2250	4.19	Gray-brown.	2.35
CLEVELAND COUNTY.																
43	81	Esbridge pit, Grover	32	Lean.	10.6	6	16.6	33	Slow.	Same to fine.	2100	2300	2500	5.72	White to Red.	2.57
44	82	Powhatan Clay Mfg. Co.'s pit, S. W. of Grover	28	Good.	8	5	13	39	Slow.	Fine.	2100	2300	2500	4.71	Whitish.	2.34
45	83	Powhatan Clay Mfg Co.'s pit, ½ mile E. of Grover	31	Lean.	4	4.5	8.5	31	Very slow.	Coarse.	2150	2350	2550	5.07	Whitish.	2.51
46	108	Under clay, Cleveland Brick Co., S. of Grover	35	Good.	9	6.5	15.5	98	Slow.	Medium.	1900	2100	2300	5.67	Light red.	2.36
47	109	Upper clay, Cleveland Brick Co., S. of Grover	35	Lean.	7.5	5	12.5	42	Fast.	Medium.	1950	2150	2350	6.23	Red.	2.61
CUMBERLAND COUNTY.																
14	110	E. A. Poe's pit, ½ mile S. of Fayetteville; average clay	28	Good.	8.5	5	13.5	144	Quickly.	Medium.	1900	2050	2200	10.44	Red.	2.55
15	111	E. A. Poe's pit, ½ mile S. of Fayetteville; "tough" clay	28.5	Fair.	9.8	7	16.8	84	Slow.	Fine.	1850	2050	2250	11.40	Red.	2.45
FORSYTH COUNTY.																
82	112	Lower brick-clay, Bethania	25	Good.	10	5	15	127	Slow.	Coarse.	1900	2100	2300	8.13	Red.	2.50
83	112	Upper " "	27	Lean.	8.5	6	14.5	95	Slow.	Coarse.	2000	2150	2300	13.70	Red.	2.51

GASTON COUNTY.																
113	Mount Holly, brick-clay	29	Good.	8	4.5	12.5	131	160	Slow.	F'ine.	1950	2100	2250	6.98	Red.	2.47
GUILFORD COUNTY.																
115	Green's clay pit, Greensboro.	28	Lean.	10	6	16	68	77	Fast.	Coarse.	2100	2400	2500	7.97	Red.	2.46
114	Greensboro Brick & Tile Co.'s pit.	28	Slight.	9	6	15	85	96	Fast.	Coarse.	2050	2250	2450	11.83	Red.	2.44
115	Brick-clay, Dean's brickyard, Greensboro	28	Lean.	10	6	16	66	77	Fast.	Medium.	2100	2300	2400	7.97	Red.	2.46
116	Kirkpatrick's clay pit, Greensboro	30	High.	11	5	16	220	237	Slow.		1900	2100	2300	12.04	Red.	2.48
81	Fire-clay, first pit, Pomona Terracotta Co.	26	Lean.	10	2	12	47	49	Slow.	Coarse.	2150	2350	2550	4.66	Buff.	2.55
85	Under fire-clay, Pomona Terracotta Co.	33	"	3	6	14	16	16	Slow.	Coarse.	2200	2400	2600	7.99	Gray-buff.	2.52
89	Under pipe-clay, first pit, Pomona	40	Good.	10	6	16	86	103	Slow.	Coarse.	2050	2250	2450	5.10	Red.	2.55
114	Brick clay. Greensboro Brick & Tile Co.'s brickyard.	28	Good.	9	6	15	85	96	Fast.	Coarse.	2050	2250	2450	11.83	Red.	2.44
84	Upper clay, Pomona Terracotta Co.	30	Lean.	10	6	16	59	67	Fast.	Coarse.	2000	2150	2300	11.01	Red-brown.	2.50
90	Pipe-clay, second pit, Pomona.	33	Good.	8	3	11	115	160	Slow.	Coarse.	2000	2200	2400	7.27	"	2.51
85	Woodroffe's fire-clay, 1 mile N. of Pomona.	28	Lean.	9.3	4	13.3	51	56	Slow.	Coarse.	2100	2300	2500	5.83	Light red.	2.60
HALIFAX COUNTY.																
117	Upper sandy clay, Roanoke Rapids.	25	Lean.	8	5	13	46	50	Very slow.	Coarse.	1900	2050	2250	11.64	Red.	2.39
117	Middle clay.	26.5	Good.	10	5	15	151	168	Fast.	Medium.	1900	2050	2250	9.06	Red.	2.59
118	Under "	26	Very good.	10.6	5	15.6	206	218	Fast.	"	1900	2050	2250	13.24	Red.	2.56
HARNETT COUNTY.																
119	Clay, C. F. & Y. V. R. R., 92-93 mile post.	35	Lean.	10	4	14	27	31	Fast.	Very fine.	1850	2150	2350	3.81	Red-buff.	2.43
120	S. E. of Spout Springs.															
120	Clay, C. F. & Y. V. R. R., 100 mile post.	32	"	8	6	14	24	29	"	"	1850	2150	2350	3.96	Red.	2.53
121	S. E. of Spout Springs.	35	"	9	8	17	19	25	"	"	2000	2300	2400	6.24	Red-gray.	2.41
121	Clay, just W. of Spout Springs station.															
JACKSON COUNTY.																
61	Washed kaolin, Harris Clay Co., near Webster	42	Lean.	6	4	10	20	22	Slow.	Very fine.	2300	2500	2700	4.75	White.	2.43
62	Crude kaolin, Springer mine, near Webster	33	Lean.	2	4	6	6	7	Fast.	Coarse to fine.	2300	2500	2700	2.70	"	2.58
62	Washed kaolin, Springer mine, near Webster	38	Lean.	8	4.5	12.5	23	24	Slow.	Very fine.	2350	2550	2700	2.15	"	2.27
59	Washed kaolin, N. C. Mining & Mfg. Co., near Sylva	40	Lean.	8	4	12	15	15	Slow.	Very fine.	2200	2450	2700	2.99	"	2.31
121	Brick-clay, 3/4 mile S. of Sylva.	28	Fair.	9	5	14	58	67	Slow.	Coarse to fine.	2100	2300	2500	6.08	Red.	2.59
LINCOLN COUNTY.																
77	Pottery clay, T. Rhodes place, 2 miles N. W. of Lincolnton.	35	Good.	10	7	17	157	186	Slow.	Fine.	1900	2100	2300	6.46	Dark red.	2.51
78	Pottery clay, T. Rhodes place, 2 1/2 miles N. W. of Lincolnton.	40	"	9.5	5.5	15	183	158	Slow.	Fine.	1900	2100	2300	6.42	Red.	2.53

Field Number.	Page in Report where described.	LOCALITY.	Per cent. water added to give workable paste.	Plasticity.	PERCENTAGE.			Average tensile strength.		Character of Shaking.	Texture of Clay.	DEGREES FAHR.			Total Fluxes.	Color when burned.	Specific Gravity.
					Air Shrinkage.	Pipe Shrinkage.	Total Shrinkage.	Lbs. per sq. in.	Max. tensile strength.			Incipient Fusion.	Viscosity.				
60	63	MACON COUNTY. Crude kaolin, near West's Mill, Brindel's land.....	31	Lean.	6	6	12	15	18	Slow.	Fine.	2300	2900	Abv. 2700	2.47	White.	2.31
66	122	MARTIN COUNTY. Brick-clay, Wm. Biggs.....	40	Lean.	13	3	16	67	78	Fast.	Coarse.	2000	2150	2300		Red.	
39	123	MECKLENBURG COUNTY. D. K. Cecil's yard, Charlotte.....	25.8	Fair.	6	6	12	88	95	Fast.	Fine.	1850	2050	2250	12.15	Red.	2.68
41	124	" " " " " "	35	Lean.	5	4	9	26	24	Slow.	Coarse.	2100	2300	2500	12.30	Reddish.	2.44
42	124	F. W. Shuman's yard, Charlotte.....	35	Good.	13.3	8	21.3	105	125	Med. Fast.	Medium.	1950	2100	2350	12.98	Red.	2.60
62	125	Upper clay, J. Asbury's yard, Charlotte	25	Very Plastic.	7	5	12	60	72	Fast.	Coarse.	1900	2100	2300	10.92	Red.	2.60
64	65	MONTGOMERY COUNTY. Dark kaolin, washed, 4 miles W. of Troy.	30	Lean.	3	10	13	9	12	Fast.	Fine.	2100	2300	2500	3.35	Pale buff.	2.32
68	65	White kaolin, washed, 4 miles W. of Troy.	31	Lean.	3	6	9	11	14	Fast.	Fine.	2100	2300	2550	5.11	Yel. white	2.34
20	66	RICHMOND COUNTY. Kaolin, near Bostick's Mills.....	27.7	Lean.	4	9	13	10	14	Slow.	Fine.	2250	2500	2700	3.43	Yel. white	2.41
21	66	" " " " " "	26	Lean.	3.5	8	11.5	13	16	Slow.	Fine.	2300	2500	2700	5.00	Yel. white	2.52
22	67	" " " " " "	27.7	Lean.	4	8	12	15	16	Slow.	Fine.	2250	2450	2700	4.32	Yel. white	2.43
20	68	Washed kaolin, near Bostick's Mills ..	26	Lean.	3	9	12	10	12	Slow.	Fine.	2250	2450	2700		Yellow.	
22	67	" " " " " "	29	Lean.	4	7	11	8	11	Slow.	Fine.	2250	2450	2700		Faint yel. tint.	
23	126	R. L. Steele's pit, 4 miles north of Rockingham.....	26	Good.	6	8	14	133	154	Slow.	Medium.	2000	2200	2400	8.11	Red.	2.54
19	126	ROBESON COUNTY. Brick-clay, Red Springs.....	17	Lean.	8.8	4	12.8	41	51	Fast.	Coarse.	2100	2250	2400	7.62	Red.	2.60
48	127	ROWAN COUNTY. Brick-clay, D. K. Cecil, Salisbury.....	28	Good.	8.5	5.5	14	129	144	Slow.	Fine.	1850	2050	2250	5.80	Red.	
38	128	SURRY COUNTY. Pomona Sewer-pipe Co.'s pit, 1 mile N. W. of Elkin.....	16	Lean.	7	9	16	69	73	Slow.	Med. Fine.	1900	2100	2300	13.53	Red.	2.59
40	129	UNION COUNTY. J. T. Shute's pit, Monroe.....	23	Good.	6	3	9	124	148	Slow.	Medium.	1950	2150	2350	7.28	Red.	

BIBLIOGRAPHY.

Such a list could be made to include thousands of titles, but all that is intended here is to give the titles to the more important and easily obtained works on clays and the manufacture of clay products.

The German works contain much that is of importance on the technology of clay-working, and many of them can be obtained at reasonable rates.

For an exhaustive index the reader is referred to the Bulletin of the U. S. Geological Survey, by J. C. Branner, given below.

The articles which are mainly locality reports are marked *a*; those dealing largely with the technology alone, *b*; reports treating of both are marked *c*.

Barber, E. A. Pottery and Porcelain of the United States. New York, 1893. (Historic.)

Bischof, C. Die Feuerfesten Thone. Leipzig, 1895 (*b*).

Blue, A. Vitrified Bricks for Pavements, 3d Ann. Rept. Ontario Bureau of Mines, p. 103. Toronto, 1893 (*b*).

Blatchley, W. S. Clays of Coal-bearing Counties of Indiana, Ind. Geol. Surv., 20th Ann. Rept., p. 24, 1896 (*c*).

Bock, O. Die Ziegelei-Industrie. Leipzig.

Branner, J. C. Bibliography of Clays and the Ceramic Arts, Bull. U. S. Geol. Surv. No. 143, 1896.

Chamberlin, T. C. Geol. of Wisconsin, vol. II, p. 235, 1877, and I, p. 668, 1883. Describes Milwaukee brick and clay (*a*).

Cook, G. H. Clays of New Jersey, Geol. Surv. N. J., 1878 (*a*).

Cook, R. A. Manufacture of Fire-brick at Mt. Savage, Md., Trans. Amer. Inst. Min. Eng., vol. XIV, p. 698, 1886 (*b*).

Cox, E. T. Porcelain, Tile and Potters' Clays, Ind. Geol. Surv., 1878, p. 154 (*a*).

Davis, C. T. Bricks, Tiles and Terra Cotta. Philadelphia, 1884, second edition 1889 (*b*).

Dummler, K. Ziegel und Thonwaaren Industrie in den Vereinigten Staaten. Halle, 1894 (*b*).

Griffiths, H. H. Clay Glazes and Enamels. Indianapolis, 1895 (*b*).

Hill, R. T. Clays of the United States, U. S. Geol. Survey, Mineral Resources, 1891, p. 474 (*a*).

Hofman and Demond. Tests on the Refractory Character of Fire-clays, Trans. Amer. Inst. Min. Eng., vol. XXIV, p. 42, 1895 (*b*).

Holmes, J. A. The Kaolin and Clay Deposits of North Carolina, Trans. Am. Inst. Min. Eng. XXV, p. 929, 1896 (a).

Irelan, L. Pottery, 9th Ann. Rept. Cal. State Mineralogist, p. 240, 1890 (b).

Johnson, W. D. Clays of California, 9th Ann. Report. Cal. State Mineralogist, p. 287, 1890 (a).

Kerr, W. C. Geology of North Carolina, vol. I, 1875, pp. 296, 297.

Ladd, G. Clays of St. Louis County, Mo., Bull. Mo. Geol. Surv. No. 3, 1890 (a).

Langenbeck, K. Chemistry of Pottery. Easton, 1896 (b).

Lesley, J. P. Kaolin Deposits of Delaware and Chester Counties, Pa., Ann. Rept. Pa. Geol. Survey, p. 571, 1885 (c).

Loughridge, R. H. Clays of Jackson Purchase Region, Kentucky, Kentucky Geol. Surv., p. 77, 1888 (a).

Meade, D. W. Manufacture of Paving Brick, Trans. Amer. Soc. Civ. Eng., vol. XXIV, p. 553, 1893 (b).

Orton, Edward, Jr. Clays and Clay-working Industries of Ohio, Ohio Geol. Survey, vol. VII, part I, p. 69, 1893 (b).

Periodicals:

Brick (monthly), Chicago, Ill.

Brickbuilder (monthly), Boston, Mass.

Brickmaker (bi-weekly), Chicago, Ill.

Clay (quarterly), Willoughby, O.

Crockery and Glassware Journal (weekly), N. Y.

Clay-worker (monthly), Indianapolis, Ind.

Paving and Municipal Engineering, Indianapolis, Ind.

Thonindustrie Zeitung, Berlin, Germany.

Töpfer- und Ziegler-Zeitung, Berlin, Germany.

Phillips, Wm. B. Eng. Min. Jour., XLII, p. 326; and Jour. Iron and Steel Industry, 1887, No. 1, p. 389 (c).

Platt, F. Test of Fire-Brick, Pa. Geol. Survey, Rept. M. M., p. 270, 1879 (b).

Ries, H. Clays of United States, Mineral Industry, 1894, vol. II (c).

Ries, H. Clays of Hudson River Valley, 10th Ann. Rept. of N. Y. State Geologist, 1890 (c).

Ries, H. Clay Industries of New York, Bull. N. Y. State Museum, vol. III, No. 12, 1895 (c).

Ries, H. Technology of Clay-working Industry and Analyses of Clays of U. S., U. S. Geol. Surv., 16th Ann. Rept., pt. IV, p. 523 (b).

Ries, H. Pottery Industry of United States, 17th Ann. Rept. U. S. Geol. Survey, pt. III, p. 842 (b).

Ries, H. The Clays of Florida, 17th Ann. Rept. U. S. Geol. Survey, pt. III, p. 871 (*a*).

Ries, H. Clays of Alabama, Bull. Ala. Geol. Survey, 1897 (*a*).

Ries, H. The Clay-working Industry in 1896, 18th Ann. Rept. U. S. Geol. Survey, pt. V, p. 1105, 1897 (*c*).

Ries, H. The Ultimate and Rational analysis of Clays and their relative advantages, Trans. Amer. Inst. Min. Eng., XXVII.

Smith, E. A. Clays of Alabama, Ala. Indus. and Sci. Soc., vol. II, 1892 (*a*).

Smock, J. C. Mining Clays in New Jersey, Trans. Amer. Inst. Min. Eng., III, p. 211, 1874-75 (*b*).

Smock, J. C. New Jersey Clays, *ibid.*, vol. VI, p. 177, 1879 (*a*).

Spencer, J. W. Clays of Georgia, Ga. Geol. Surv., p. 276, 1893 (*a*).

Struthers, J. Le Chatelier Thermo-electric Pyrometer, School of Mines Quarterly, vol. XII, p. 143, and vol. XIII, p. 221 (*b*).

Wheeler, H. A. Fusibility of Clays, Eng. and Min. Jour., XVII, p. 224, 1894.

Wheeler, H. A. Vitrified Paving Brick. Indianapolis, 1895.

Wheeler, H. A. Clays of Missouri, Mo. Geol. Survey, vol. XI, 1896.

Young, Jennie J. Ceramic Art. New York, 1878 (*b*).

Zwick, F. Die Ziegel Industrie. Leipzig, 1894.

INDEX.

	PAGE
Absorption of water by clays.....	42
Air-drying of clays.....	26
Alabama clays, silica in	24
Aleksiejew cited.....	34
Alkalies in clay	16, 17, 18
advantage of	18
coloring influence of, in.....	18
determination of, in clay	27
fixed in clay	16
soluble alkaline compounds	17
" sulphates as fluxes.....	17
insoluble " " "	17
silicates as fluxes	18
Aluminium oxide in clay, determination of..	28
Ammonia in clay	16
Analyses of clays (see brick-clay, fire-clay, pottery-clay, pipe-clay and kaolin), ...	142, 149
methods of making	27
rational analyses	9, 29, 30
Asbury's brickyard	125
Auger machine	97
Asheville, brick-clay near	104
Baskerville, Chas., analyses by	9, 27
quoted	27
Bibliography.....	150
Biltmore, brick-clay near.....	106
Bischof, C., quoted	24, 36
Blackburn, pottery industry at	76
Bostick, kaolin near.....	65
Brick-clay deposits in North Carolina.....	92, 102
Brick for building	93
effect of calcium carbonate on	21
manufacture, methods of	94
soft-mud process	94
stiff- " "	96
dry-press "	99
Brick-clays and brick manufacture.....	92
Brick-clays, general characters of	92
effect of sand on	93
requisites of	93
analyses of	103, 104, 105, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 132, 133, 134, 135, 136, 137, 138.
preparation of.....	94, 96, 100
tempering	94, 96
molding.....	95, 97, 101
burning.....	95, 98, 101
Brick-clay, deposits in North Carolina	102
in Bladen county	102
near Prospect Hall	102

	PAGE
Brick-clay, in Bladen County, on property of Wm. Whitted.....	102
in Buncombe county.....	104
Penniman's clay bank, near Emma	104
near Asheville and Biltmore.....	106
near Fletcher	106
Buncombe Brick Co.....	106
in Burke Co	107
near Morganton	107
in Cleveland Co	108
near Grover	108
in Cumberland Co	110
near Fayetteville....	110
in Forsyth Co	111
near Bethania	111
Carter & Shepherd's clay b'k.....	113
in Gaston Co.....	113
near Mt. Holly	113
in Guilford Co	114
near Greensboro.....	114
Dean's brickyard	115
Kirkpatrick's brickyard	115
Watson's brickyard	115
in Halifax Co.....	116
near Roanoke Rapids.....	116
" Weldon	119
" Halifax	119
in Harnett Co	119
near Spout Springs	119
in Jackson Co.....	121
near Sylva	121
in Martin Co	122
near Williamston	122
in Mecklenburg Co	122
near Charlotte	122
Cecil's yard	123
Houser's yard.....	123
Sassamon's yard	123
Shuman's deposit.....	124
Asbury's brickyard.	125
in Richmond Co.	125
near Rockingham.....	125
in Robeson Co.....	126
near Red Springs	126
in Rowan Co.....	127
near Salisbury	127
in Surry Co.....	128
near Elkin	128
in Union Co	129
near Monroe	129
Shute's clay-bank	129
in Wake Co.....	130

- Brick-clay, in Wake Co., near Raleigh 130
 in Wake Co., Penitentiary brick
 yard 130, 131
 Green's property 131
 Caraleigh Mills Co. 131
 in Wayne Co. 131
 near Goldsboro 131
 Goldsboro Brick and Tile Co. 131
 Well & Bros. yard 133
 in Wilkes Co. 134
 Smoak's yard 134
 in Wilson Co. 136
 near Wilson 136
 Lucas property 137
 Brindel's kaolin deposit 62
 Buncombe Brick Co. 106
 Burke Co., pottery industry in 75
 brick-clays in 107
 Burning brick 94, 95, 96, 98, 101
 updraft kilns 98
 continuous kilns 98
 Calcium carbonate in clay 21
 effect on brick 21
 Calcium oxide in clay 28
 Caraleigh Mills, brick-clay at 130
 Carbonate of iron as source of iron in clays 19
 Carbonic acid, action on feldspar 12
 Carter and Shepard's clay bank 113
 Catawba county, pottery industry in 76
 Cecil's brickyard 123
 Clay substance 14
 Clay, absorption of water 42
 absorbing lime 22
 alkalies in 16
 ammonia in 16
 analyses of 142-149
 bases in 11, 15, 16, 17, 18, 20, 21, 22, 23
 brick (see brick-clay) 92
 chemical analysis of 27
 chemical properties of 15
 china 50
 character of for paving-brick 139
 color of, unburned 20
 color of 43
 composition of (see analyses) 11
 compounds of iron in 18, 19, 20
 comparison of, from Wilson and
 Wayne counties 138
 Cretaceous and Tertiary 12
 defined 11
 density of 43
 effect of calcium carbonate in, on
 brick 21
 Forsyth county 111
 near Fayetteville 110
 fire-shrinkage of 35
 fire-clay (see fire-clays, p. 155).
 fluxing impurities in 15-23
 fusibility of 36
 geology and geography of, in N. C. 44
 hornblende in 12
 impurities in 15
 lime in 15, 20
 magnesia in 15, 23
 Clay, non-fluxing impurities in 23
 origin of 11
 organic matter in 25
 pipe-clay in North Carolina 66
 plasticity of 25, 26, 33, 34
 preparation of 54, 94, 96, 100
 properties of 11, 14
 pure, composition of 11, 14
 purity of, depends on 12
 physical properties of 33, 42
 pottery clays in N. C. 71
 pottery clay, requisites of 72
 removing lime from 21
 residual clays (see residual) 12, 44, 92
 substance 14
 sedimentary 12, 13, 46, 92
 shrinkage of 35
 silica in 24
 silica, two classes of, in 24
 silica, free, in 24
 silica in Alabama clays 24
 " " North Carolina 24
 slaking of 42
 sulphuric acid in 15
 taste of 43
 tempering the 94, 96
 temperature at which clay fuses 37
 tensile strength of 34, 35
 texture of 42
 titanium in 24
 variation in composition of 13, 14
 water in 26
 working industries 48
 Clay, brick, near Asheville 106
 Bethania 111
 Biltmore 106
 Charlotte 122
 Elkin 128
 Fayetteville 110
 Fletcher 106
 Goldsboro 131
 Greensboro 114
 Grover 108
 Halifax 119
 Monroe 129
 Morganton 107
 Mount Holly 113
 Prospect Hall 102
 Raleigh 130
 Red Springs 126
 Rookingham 125
 Roanoke Rapids 116
 Salisbury 127
 Spout Springs 119
 Sylva 121
 Weldon 119
 Williamston 123
 Wilson 136
 Wilkesboro 134
 Clays from Wilson and Wayne counties
 compared 138
 Clay deposits, geology and geography of
 North Carolina 44
 Cleveland county, fire-clays in 61

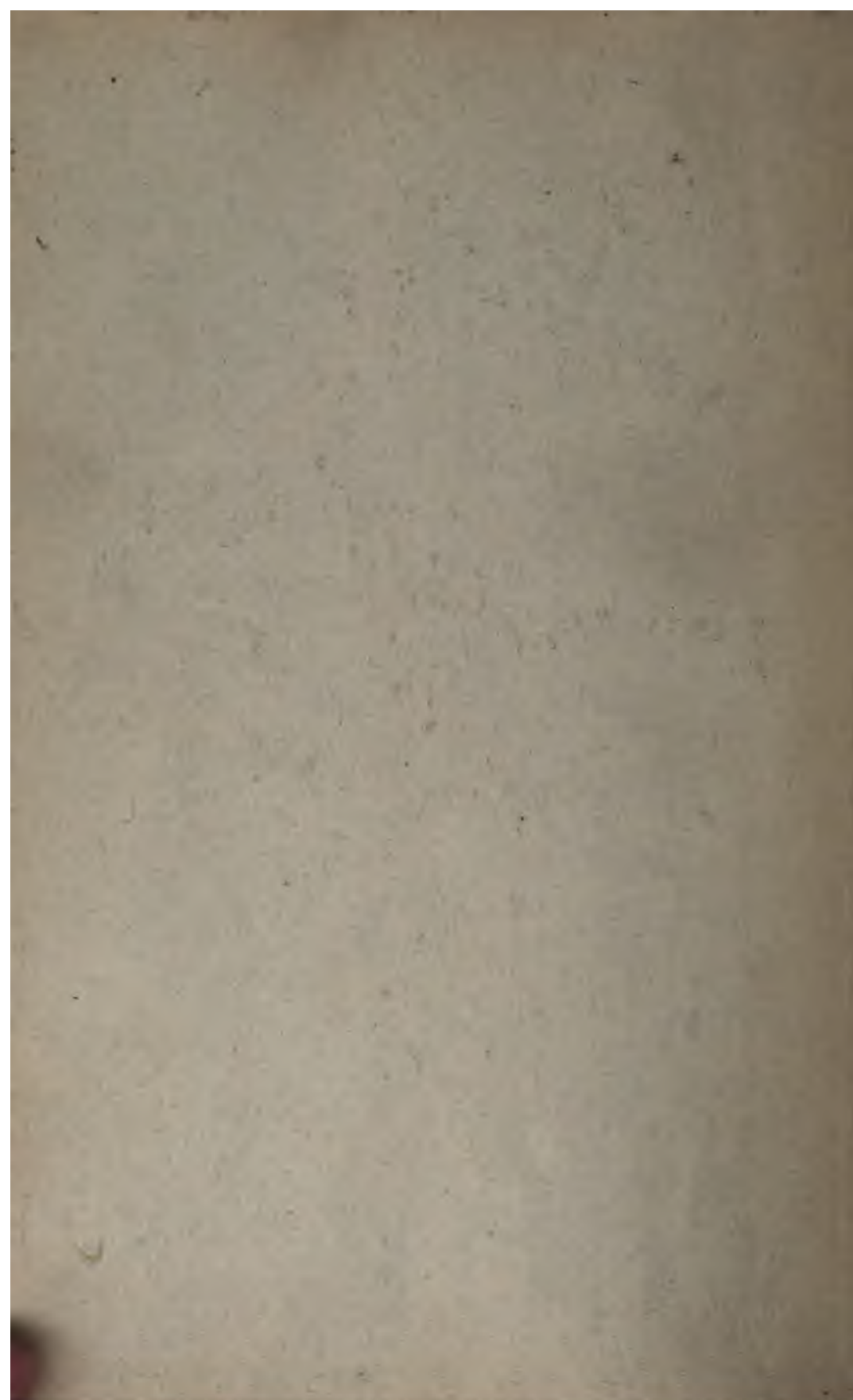
- Cleveland county, brick-clays in 108
 Cook, Prof. G. H., quoted.....33
 Continuous kilns 98
 Coal mixed with clay in burning brick 96
 Color of clays 43
 Compounds of iron in clay 18
 Combined water in clay.....26
 Cramer cited.....25
 Crematachenski cited 34
 Deane's brickyard 115
 Density of clays 43
 Deposits of kaolin in North Carolina 58
 Dry-press process 99
 preparation of clay for 100
 molding in 101
 burning the brick in 101
 Determination of moisture in clay 27
 water " " 27
 alkalies " " 27
 silica " " 27, 28
 iron sesquioxide 28
 aluminium oxide 28
 calcium " 28
 magnesium " 28
 insoluble residue 28
 titanic oxide 29
 sulphur 29
 ferrous oxide 29
 rational analyses.....29
 Distribution of the kaolins 50
 Elkin, brick-clay near 128
 Emma, Penniman's clay bank near 104
 Fayetteville, brick-clay near 110
 Feldspar, orthoclase 11, 17, 18
 action when fused 16
 alkalies in 16, 17, 18
 weathering of 12
 Ferric oxide in clay 19
 percentage desirable 20
 Ferric silicate in clay, effect of 19
 Fire-brick, manufactured 48
 Fire-clays 80
 characteristics of 80
 analyses of 81, 82, 83, 84, 85
 in Cleveland Co 81
 near Grover 81
 in Guilford Co 83
 Pomona clay-bank 83
 Woodroffe clay-bank.....85
 Fletcher, brick-clay near.....106
 Fluxes, in clay, per cent. of, 16, 17, 18, 19, 20, 21, 22
 Fluxing impurities in clay 15-23
 Forsyth county, brick-clays in.....111
 Fusion of clay, incipient.....36
 stages of 36
 temperature of 37
 Fusion temperatures, table showing.....39-41
 Fusibility of clay 36
 Gaston county, brick-clay in.....113
 Geology and geography of North Carolina
 clays 44
 Goldsboro, brick-clays near 131
 Goldsboro Brick and Tile Co 131
 Greensboro, brick-clay near.....114
 Greensboro Brick and Tile Co.'s yard 114
 Green's property 131
 Grover Brick Company 81
 Grover, brick-clays near.....108
 Gypsum in clays 22
 Guilford county, fire-clays in 83
 Pomona clay-bank.....83
 Woodroffe clay-bank 85
 pipe-clays in.....88
 Pomona Terra Cotta Co.'s
 works 88
 brick-clay in.....114
 Halifax county, clay in 116
 brick-clays near 119
 Harris Clay Co.....59
 Harnett county, brick-clays in.....119
 Hematite, an impurity in clay.....18, 19
 Houser's brickyard.....123
 Holmes, J. A., cited.....46
 Hornblende in clays 23
 Hygroscopic water in clay.....26
 Ignition, loss on, in clay 27
 Industry, clay working in North Carolina.....48
 pottery, The.....71
 Impurities in clay.....15, 16, 17, 18, 19, 20, 21, 22, 23,
 24, 25
 fluxing impurities 16
 non-fluxing impurities 23
 in residual clay 12
 Infusibility of kaolinite 15
 Insoluble residue, determination of.....28
 Iron compounds in clay 18, 19, 20
 Iron sesquioxide, determination of 28
 Iron, a coloring agent.....19, 20
 percentage permissible in clay 20
 " in N. C. kaolins 20
 sources of, in clay 18
 Incipient fusion of clay.....36
 Jackson county.....58
 brick-clay in 121
 kaolin in.....58, 59, 60, 61, 62
 Jolly-wheel.....74
 Kaolin, analyses of.....59, 61, 62, 63, 65, 67, 68, 69
 Kaolin, Bostick's Mills 65
 china clay 50
 comparisons of North Carolina with
 foreign ones 69
 composition of 52
 distribution of 50
 fluxes in.....16
 Harris Clay Co.'s mine.....59
 iron in 53
 Jackson county.....58
 mineralogical character of 50
 mining of.....53
 Montgomery county 64
 North Carolina Mining and Mfg. Co.'s
 mine 58
 preparation of.....54
 plasticity of, increase by grinding..15
 properties of 51
 Richmond county 65
 Springer's pit 61
 Steele's deposit.....65

- Kaolin, Sylva 58
 Troy 64
 uses of, North Carolina 68
 Wests Mill 62
 Webster 59
 Kaolinite, composition of 11, 12
 described 15
 formation of 11
 origin of 11
 refractoriness of 15
 Kilns..... 98
 up-draft 98
 continuous..... 98
 Kirkpatrick's brickyard 115
 Langenbeck cited 59
 Lime, compounds of, in clays 20, 21, 22
 absorption of into clays 22
 as carbonate, effect on clay 21
 as silicate, " " 21
 as sulphate, " " 21, 22
 effect on brick 21
 in North Carolina clays 23
 Limonite, a frequent impurity in clays... 18, 19
 Lincoln county, pottery industry in 77
 Lincolnton, pottery industry near 77
 Lithia in clays 16
 Lucag, brickyards of 187
 Macon county, kaolin in 62
 Magnesia, origin of, in clay 23
 in clays 23
 in North Carolina clays 23
 Magnesium carbonate... 23
 oxide in clay, determination of 28
 sulphate 23
 Manufacture of brick 92
 of stoneware 73
 of sewer-pipe and tiles .. 86
 of paving-brick 139, 140
 Martin county, brick-clay in 122
 McDowell, Manly, pottery clay 75
 Measurement of temperature 38
 Mecklenburg county, brick-clay in 122
 Methods employed in making clay analyses. 27
 Methods of brick manufacture 94
 soft-mud process 94
 stiff-mud process 96
 semi-dry press 94, 101
 dry-press 99
 Mineral impurities in clay 15
 Mining of kaolin 53
 Moisture in clays 26
 hygroscopic 26
 chemically combined 26
 determination of 27
 Molding brick 94, 95, 97, 101
 Monroe, brick-clays near 129
 Montgomery county, kaolin in 64
 Morganton, pottery industry near 75
 brick-clays near 107
 Mount Holly, brick-clays near 113
 Non-fusing impurities in clay 23
 North Carolina clay-working industry, The. 48
 deposits of kaolin in 58
 pottery clays in 71
 North Carolina fire-clays and pipe-clays in.. 80
 pipe-clays in 86
 brick-clay deposits in 102
 clays, silica in 24
 Olschewsky quoted 34, 140
 Organic matter in clays 25
 effect of, on clay 25
 Origin of clays 11
 Orton, E., Jr., cited 84, 140
 Oxides in clay 15, 18
 Oxygen, a weathering agent 12
 Paving brick, manufacture of 139, 140, 141
 analysis of clay for 139
 character of clay requisite for 139
 kilns for 140, 141
 Penitentiary yard, Raleigh, brick-clay at . 130
 Penniman, clay bank, near Emma 104
 Percentage of iron admissible in clay 20
 in N. C. kaolins 20
 Physical properties of clay 33, 42
 Pipe-clays in North Carolina 86
 analyses of 89, 90
 methods of manufacture 86, 87, 88
 in Guilford county 88
 Pomona Terra Cotta Co's works, 88
 requirements of 86
 tensile strength of 86
 Plasticity in clays 34
 in kaolinite increased by grind-
 ing 15
 effect of organic matter on 25
 Poe & Bros. yard 110
 Pomona Terra Cotta Co 83, 88
 Sewer-pipe and Brick Co 86
 Potash in clay 11, 15, 16, 18
 Pottery clays in North Carolina 71
 Pottery clay, requisites of 72
 analyses of 75, 76, 77, 78, 79
 Burke county 75
 Blackburn 76
 Catawba county 76
 Cowles, Calvin 79
 Lincoln county 77
 near Lincolnton 77
 Rhodes, T 77
 Wilkes county 78
 Wilkesboro 78
 Pottery industry, The 71
 in Burke county 75
 at Blackburn 76
 in Catawba county 76
 in Lincoln county 77
 near Lincolnton 77
 near Morganton 75
 in Wilkes county 78
 in Wilkesboro 78
 Powhatan Clay Mfg. Co 81, 82
 Preparation of clay for bricks 94, 96, 100
 fire-clay 80, 81
 kaolin 54, 55, 56, 57, 58
 pipe-clay 86
 pottery-clay 72
 clay for paving-bricks 140

- Pressed brick 49
 Properties of kaolin 51
 Prospect Hill clays 102, 103, 104
 Pyramide, Seger's 88
 Pyrite in clay 18, 19
 Pyrometers 88
 Thermo-electric, The 88
 Seger's pyramids 88
 Purity of clay depends on 12
 Raleigh, brick clays near 130
 Rational analysis of clay, The 80
 method of making 29
 practical bearing of 31
 Refractoriness of clay 37
 Requisites of a brick-clay 93
 fire-clay 80
 pipe-clay 86
 Red Springs, brick-clay, near 126
 Residual clays 12, 44, 92
 composition of 45
 impurities in 12
 Residue, insoluble, determination of 28
 Rhodes property, pottery clay 77
 Richmond county, kaolin in 65
 brick-clay in 125
 Roanoke Rapids, brick-clay near 116
 Rockingham, brick-clay near 125
 kaolin near 65
 Roberdell, brick-clay at 125
 Robeson county, brick-clay in 126
 Rowan county, brick-clay in 127
 Salisbury, brick-clay near 127
 Sand, effect of, on brick-clays 93
 Sassamon's brickyard 123
 Sedimentary clays 46, 92
 Seger, quoted 20, 22, 52
 Seger's pyramids 38
 fusion temperatures of 39, 40, 41
 Semi-dry-press process 94, 101
 Sewer-pipe 86
 method of manufacture. .. 86, 87,
 88, 91
 Pomona Terra Cotta Co 88
 Shales, used as clays 12, 13
 metamorphism of 13
 Shrinkage of clays 35, 36
 Shute's clay-bank 129, 130
 Shuman's deposit 124
 Silica, determination of in clays 27
 in clays 24
 effects of on clays 24
 Silicates, in clay 11
 of iron in clay 18, 19
 Slaking of clays 42
 Smoak's yard 134
 Soda in clay 15, 16, 17
 Soft-mud process 94
 tempering the clay 94
 molding the brick 95
 Soft-mud burning 95
 Spout Springs, brick-clay near 119
 Springer clay-pit 61
 Stiff-mud process 96
 tempering the clay 96
 molding 97
 burning 98
 Stoneware manufacture 73, 74, 75
 Sulphur in clay, determination of 29
 Sulphates as a source of iron in clays 18, 19
 Sulphides " " " " " " " " 18, 19
 Sulphuric acid in clays 15
 Surry county, brick-clay in 128
 Sylva, brick-clay near 121
 Table of variations in clay substance 52
 Taste of clays 43
 Temperature at which clay fuses 37
 measurement of 38
 Tempering clay, soft-mud process 94
 stiff-mud " 96
 Tensile strength of clays 34
 Terra-cotta ware 88
 Company, Pomona 88
 Texture of clays 42
 Thermo-electric pyrometer, The 38
 Tiles, manufacture of 86
 Titanium in clay 24
 as a flux 25
 Titanic oxide, determination of 29
 Union county, brick-clay in 129
 Uses of North Carolina kaolin 68
 Variations in clay 13, 14
 Variation in clay substance, etc., table
 showing 52
 Viscosity of clay 36
 Vitrification of clay 36
 Wake county, brick-clays in 130
 Water in clays 26
 absorption of, by clays 42
 hygroscopic 26
 combined 26
 Watson's brickyard 115
 Wayne county, brick-clays in 131
 Weathering of feldspar 12
 Webster, kaolin near 59
 Weil & Bros. brickyard 133
 Weldon, brick-clays near 119
 Wests Mill, kaolin near 62
 Wheeler cited 34, 37, 139
 Whitted, William, clay on land of 102
 Wilson county clays 136
 brick-clays in 136
 Wilson, brick-clays near 136
 Wilkes county " " in 134
 pottery industry in 78
 Wilkesboro, pottery industry near 78
 brick-clays near 134
 Williamston " " " 122

ty-





10 AFTER 114414

1

